Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-68

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DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-68

30 September 1994

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

Photo 1 : Launch of Shuttle Mission STS-68

1.0 SUMMARY

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 17 August 1994. The detailed walkdown of Pad 39A and MLP-1 also included the primary flight elements OV-105 Endeavour (7th flight), ET-65 (LWT 58), and BI-067 SRB's. There were no vehicle anomalies or significant debris issues.

The Final Inspection of the cryoloaded vehicle was performed on 18 August 1994 during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. Due to the ambient weather conditions at this time of year, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

The launch was aborted at T-1.9 seconds MET because of an SSME #3 Failure Identification due to the High Pressure Oxidizer Turbopump discharge temperature exceeding a redline limit.

A post drain inspection of the vehicle and pad was performed 18-19 August 1994. There was no significant damage to the vehicle as a result of the abort. However, TPS erosion occurred on the aft surfaces of the following areas of the External Tank: +Y ET/SRB vertical strut, LH2 ET/ORB umbilical cable tray clam shell, LH2 recirculation line, and LH2 feedline bellows. This erosion was caused by the alignment of the new Firex water spray nozzles and the higher operating water pressures.

Post abort film analysis showed all three SSME's formed Mach diamonds. Nothing unusual in the engine start sequence, mainstage, and subsequent shutdown was noted by NASA and Rocketdyne engineers. After SSME shutdown, a considerable amount of burning hydrogen was visible in the SSME plumes/exhaust hole area. Hydrogen exiting the SSME #2 and #1 nozzles following quench coincident with FIREX water activation re-ignited but continued moving downward into the exhaust hole.

FIREX water deluge in the Orbiter base heat shield/SSME area appeared adequate. Water directed at the LH2 and LO2 ET/ORB umbilicals from the MLP deck was also adequate and reached as high as the thrust strut-to-longeron interfaces. Although alignment of the FIREX nozzles was generally good, the stream of water covering the LO2 ET/ORB umbilical was directed at the outboard side of the +Y ET/SRB vertical strut. Water directed at the LH2 ET/ORB umbilical appeared to impinge the LH2 feedline area.

A pre-launch debris inspection of the pad and Shuttle vehicle for the second launch attempt was conducted on 29 September 1994. There were no significant facility or vehicle anomalies.

The vehicle was cryoloaded on 30 September 1994. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. One facility IPR were taken on a safety sign not removed from the FSS. Due to the ambient weather conditions at this time of year, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

After the 7:16 a.m. (local) launch on 30 September 1994, a debris walk down of Pad 39A was performed. No flight hardware or TPS materials were found. At the time of the walkdown, the LH2 TSM door was closed and external surfaces showed no signs of damage. Launch films showed the door remained open as the SSME's passed by during liftoff. Post launch data revealed the door stayed open until T+7 seconds MET. Evidence of flame intrusion and exhaust plume impingement inside the TSM was discovered during the post launch inspection. The door did not close properly due to the structural failure of brackets holding the bonnet safety pin guide tube. The brackets were replaced in all the TSM's.

A total of 118 films and videos were analyzed as part of the post launch data review. The vehicle sustained no significant damage or lost flight hardware that would have affected the mission. Two white vapor-like streaks, or trails, streamed past the RH OMS pod and crossed the SSME plume at T+36 seconds MET. Deep tile damage observed on the RH OMS pod leading edge tiles in orbit by the flight crew was most likely the result of a debris impact manifesting itself as the two white vapor trails, which may have been pulverized tile material.

Several white objects fell aft of the vehicle at T+44 seconds MET. The objects appeared to originate from the Orbiter nose area and were most likely FRCS paper covers. One of these covers may have contacted the leading edge of the vertical stabilizer and disintegrated into very small pieces. Shallow tile damage observed on the vertical stabilizer leading edge during the post landing inspection may have been caused by FRCS paper cover impacts.

On-orbit photography revealed nominal separation of SRB's from the External Tank. Separation of the ET from the Orbiter was also normal. Foam, approximately 12 inches long by 4 inches wide, was missing from an External Tank intertank stringer head forward of the bipods. The divot exposed the substrate.

Downlinked imagery of window streaks and the RH OMS pod tile damage were reviewed during the mission. The window streaks were similar in size and appearance to streaks/deposits left by FRCS paper covers and RTV bonding material documented photographically on previous flights. This was an expected occurrence.

Images of the RH OMS pod leading edge tiles showed a deep damage site (5-inches by 3-inches by 2-inches to substrate) indicative of an impact by a dense particle. A debris impact in this area could not be discerned due to the lighting conditions and atmospheric haze affecting the tracking films. However, the two white vapor-like streaks passing the RH OMS pod at T+36 seconds MET may have been pulverized tile material.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. From a debris standpoint, both SRB's were in good condition. Both frustums had a combined total of 41 MSA-2 debonds.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-105 Endeavour was conducted on the runway at Dryden Flight Research Center/Edwards AFB. The Orbiter TPS sustained a total of 110 hits, of which 15 had a major dimension of one inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, both the total number of debris hits and the number of hits 1-inch or larger was slightly less than average. The Orbiter lower surface had a total of 59 hits, of which 9 had a major dimension of 1-inch or larger. The ET/Orbiter separation devices functioned properly. No debris was found on the runway below the umbilical cavities.

The largest tile damage site on the Orbiter was located on the RH OMS pod forward facing surface and measured 5 inches by 5 inches by 2 inches. This damage site had not been significantly changed by re-entry aerodynamics/heating from the condition observed in the on-orbit video review. The missing window #8 perimeter tile V070-390068-059 piece, reported by the flight crew two days into the flight, most likely caused this damage. The edge of the tile fragment is believed to be the source of three small tears/scuff marks on the payload bay doors in a line between the original tile location and the damage site on the RH OMS pod. In addition, post flight analysis of samples from the OMS pod damage site revealed the presence of black RCG tile coating material. An improper repair to the carrier panel hole with subsequent contamination of the SIP/bondline is the leading candidate for the loss of the tile (IFA STS-68-V-01).

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from the window protective covers, SRB BSM exhaust, Orbiter TPS, RCS thruster paper covers, and paints/primers from various sources. The lower surface tile damage site contained SRB Hypalon paint particles with no evidence of other non-tile material in this particular sample. The RH OMS pod tile damage sample contained pieces of black tile RCG coating and provided the additional data necessary to confirm the window #8 perimeter tile as the debris damage source. The data obtained from the post abort GOX vent system/ET footprint revealed the presence of a variety of metallic particulate. These residual sampling data do not indicate a single source of damaging debris as all of the other materials have previously been documented in post landing sample reports. The residual sample data showed no debris trends when compared to previous mission data.

A total of ten Post Launch Anomalies, including one In-Flight Anomaly (IFA), were observed during the STS-68 mission assessment.

2.0 ABORT

The launch of STS-68 was aborted at T-1.9 seconds MET because of an SSME #3 Failure Identification due to the High Pressure Oxidizer Turbopump discharge temperature exceeding a redline limit.

2.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 17 August 1994 from 0930 to 1100 hours. The detailed walkdown of Pad 39A and MLP-1 also included the primary flight elements OV-105 Endeavour (7th flight), ET-65 (LWT 58), and BI-067 SRB's. There were no vehicle anomalies or significant debris issues. Five items were entered into S0007, Appendix K for resolution prior to ET cryoload: loose MLP deck bolts near SRB HDP #3 and #8 along with various types of debris on the MLP deck, in the holddown post haunch areas, and on the sound suppression downspout deflector.

2.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 18 August 1994 from 0140 to 0255 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. Due to the ambient weather conditions at this time of year, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

Ambient weather conditions at the time of the inspection were: (not OK)

	T-3 Hours	T-0 Abort
Wind Speed (knots):	07	08
Wind Direction (degrees):	163	186
Relative Humidity (percent):	90	92
Temperature (degrees F):	73	78
Dew Point (degrees F):	70	75

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to scan the vehicle for unusual temperature gradients, particularly those areas not visible from remote fixed scanners, and to obtain a random sampling of vehicle surface temperature measurements to thermally characterize the vehicle.

2.3 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers were wet from rainfall, but intact. Less than usual ice/frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

2.4 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the fixed STI radiometers ranged from 79 to 81 degrees F. In comparison, temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 80 to 83 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 80 degrees F, which was within the required range of 44-86 degrees F.

2.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Final Inspection Team observed light condensate, but no ice/frost accumulations, on the LO2 tank. There were no TPS anomalies.

The intertank acreage exhibited no TPS anomalies. Typical ice/frost accumulation, but no unusual vapor, was present on the ET umbilical carrier plate.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice/frost accumulations, were present on the acreage.

There were no anomalies on the bipod jack pad closeouts. A crack, 8 inches long by 3/8 inch wide, was present in the -Y ET/SRB cable tray forward surface TPS. The presence of the crack was acceptable for flight per the NSTS-08303 criteria.

Typical amounts of ice/frost had accumulated in the LO2 feedline bellows while less than usual amounts of ice/frost were present in the support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. Some vapors were venting from the -Z bellows (ET side) area. The LH2 feedline bellows were filled with condensate, ice, and frost.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. The 17-inch flapper valve actuator access port foam plug was properly closed out. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The summary of Ice Team observations/anomalies consisted of three OTV items after ET cryoload and one visual inspection item after drain:

Anomaly 001 documented an 8-inch by 3/8-inch crack in the forward surface TPS of the -Y vertical strut/ET-SRB cable tray.

Anomaly 002 documented excessive ice formations around the GUCP. The accumulation of ice started after the launch abort due to a facility GH2 ice suppression problem. The condition was addressed in IPR MLP-1-147.

Anomaly 003 documented numerous black marks or residue, approximately 1-inch in diameter, in the -Y GOX vent seal footprint area.

Anomaly 004 documented ET TPS "erosion" from FIREX water on the following areas (aft surfaces): +Y SRB vertical strut and cable tray support closeout, LH2 ET/ORB umbilical feedline bellows closeout, LH2 ET/ORB umbilical cable tray fairing (clam shell) and elbow, LH2 recirculation line.

2.6 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement).

No leaks or unusual amounts of vapor were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, the GH2 vent line, or the GUCP.

No damage to the ET nosecone/footprint area was visible after the GOX vent hood was retracted. However, numerous black marks or residue, approximately 1-inch in diameter, were present in the -Y GOX vent seal footprint area.

2.7 POST DRAIN SSV/PAD WALKDOWN

A post drain inspection of the vehicle was performed at Pad-39A on 18 August 1994 from 1230 to 1415 hours.

There were 13 black marks measuring approximately 1-inch in diameter in the -Y nose cone footprint area just below the GOX vent louvers. This was the first such occurrence observed during a post drain inspection.

There were no TPS anomalies (divots or cracks) on the LO2 tank, intertank or LH2 tank acreage.

Some ice remained in the LO2 feedline support brackets, but no loose foam or TPS cracks were visible.

Bipod jack pad closeouts were intact and flush with adjacent LH2 tank-to-intertank flange closeout foam.

The 8-inch by 3/8-inch crack in the -Y ET/SRB vertical strut cable tray forward surface TPS was still visible.

TPS erosion was observed on the aft surfaces of the following areas: +Y ET/SRB vertical strut, LH2 ET/ORB umbilical cable tray clam shell, LH2 recirculation line, and LH2 feedline bellows. This erosion was caused by the alignment of the new Firex water spray nozzles and the higher operating water pressures.

Numerous damage sites (approximately 12) were visible on the orbiter base heat shield tiles with the largest site measuring 2-inches by 1-inch. The right hand OMS lower aft surface tiles appeared to have a small number of damage sites. A protruding piece of tile shim was observed at the center of the body flap upper surface.

The upper surfaces of both the right and left hand inboard elevons showed brown discolored areas that were probably the result of hydrogen burning and/or dirty deluge water.

Paint scale (debris) lay on numerous areas of the MLP deck.

No anomalies were observed on the Solid Rocket Boosters or MLP.

Other than the TPS erosion on the ET as the result of the Firex water spray impingement, no significant vehicle damage was observed during the preliminary post drain inspection.

A second inspection of the STS-68 vehicle on Pad 39A was performed on 19 August 1994 from 0930 to 1130 hours.

Orbiter SSME #3 exhibited no visible anomalies. Two repairs to the hot wall cooling tubes at the nozzle exit plane were not related to the engine anomaly.

A yellow GSE shim protruded from the center of the body flap (+Z side).

There was no TPS damage observed on the External Tank aft dome, apex, manhole cover or aft hard point closeouts.

There was no apparent TPS damage on the LO2 ET/ORB umbilical, feedline, and cable tray with the exception of a small gouge on the clam shell flange closeout inboard aft corner. TPS damage by water erosion on the +Y vertical strut appeared to be limited to an area of 12 inches by 6 inches by 1/4 inch depth (average) on the aft surface and 18 inches by 1-1/2 inches by 1/2 inch depth (max) on the outboard surface along the edge. No substrate or SLA was exposed. A protruding piece of foam immediately aft of the crossbeam showed similar erosion damage.

There was no apparent damage to the -Y vertical strut TPS.

TPS damage by FIREX water erosion occurred on the aft surface of the LH2 recirculation line and bellows closeout (Orbiter side), the LH2 feedline bellows closeout (Orbiter side), the LH2 ET/ORB umbilical cable tray near the drain hole, clam shell closeout, and flange closeout outboard aft corner. The erosion damage appeared to average 1/4-inch in depth. No damage was visible on the inboard surfaces of the LH2 ET/ORB umbilical.

Loose foam was visible in the LO2 feedline support bracket XT-1623.

Thirteen dark, circular features aft of the southwest louver on the foot print area were caused by residue/discoloration from the GOX vent seal and not the result of missing topcoat. Samples of the residue analyzed in the materials laboratory revealed pipe scale. This is a maintenance concern and a blow-down of the entire system should correct the problem.

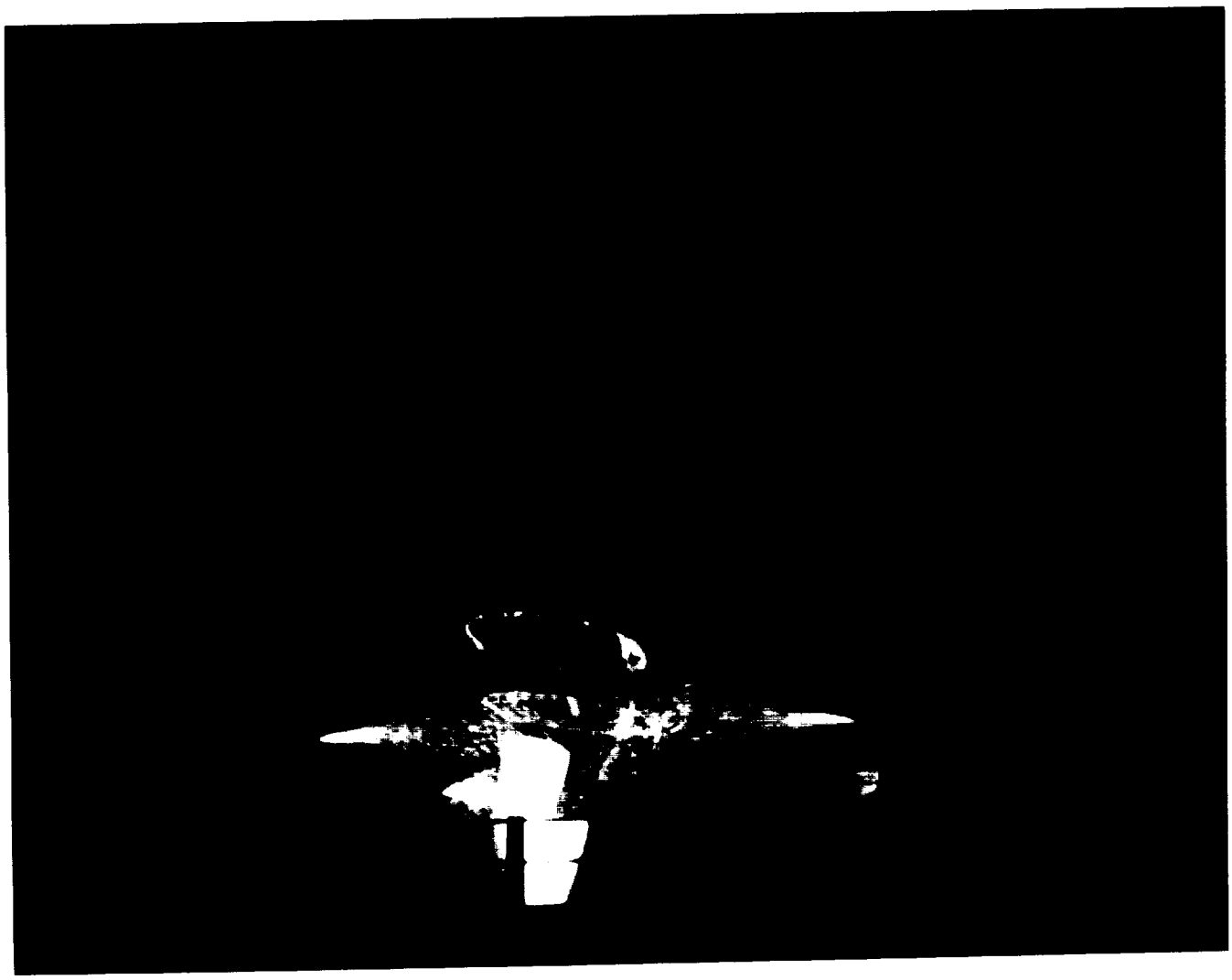

Photo 2 : SSME Shutdown During Launch Abort

Visual indication of SSME shutdown is manifested by disappearance of SSME #3 Mach diamond

Photo 3 : Free Burning Hydrogen After SSME Shutdown

Free burning hydrogen exited the SSME nozzles and drifted upward from the SSME exhaust hole

Photo 4 : Activation of FIREX Water Spray

Hydrogen from SSME shutdown re-ignites about the same time FIREX is activated

2.8 FILM REVIEW

A total of 36 films and videos, including five 35mm large format films, fifteen 16mm high speed films, and sixteen videos, were reviewed.

Igniter smoke and pre-ignition free burning hydrogen was blown under the body flap by southerly winds (OTV 063, E-5). Green vapors in the free burning hydrogen rising in the direction of the base heat shield have been observed during other SSME start sequences and are most likely the result of pad stadium lighting, pad perimeter lighting, time of day lighting, and/or burning contaminants, such as RCS paper covers, from a source external to the SSME's.

SSME ignition caused ice to fall from the LH2 and LO2 ET/ORB umbilicals. In some cases, the ice contacted tiles along the aft edge of the umbilical cavities, but no tile damage was visible (OTV 009).

All three SSME's formed Mach diamonds. Nothing unusual in the engine start sequence, mainstage, and subsequent shutdown was noted by NASA and Rocketdyne engineers. After SSME shutdown, a considerable amount of burning hydrogen was visible in the SSME plumes/exhaust hole area. Hydrogen exiting the SSME #2 and #1 nozzles following quench coincident with FIREX water activation re-ignited but continued moving downward into the exhaust hole (E-2, -3, -19, -20, -76, -77).

FIREX water deluge in the Orbiter base heat shield/SSME area appeared adequate. Water directed at the LH2 and LO2 ET/ORB umbilicals from the MLP deck was also adequate and reached as high as the thrust strut-to-longeron interfaces. Although alignment of the FIREX nozzles was generally good, the stream of water covering the LO2 ET/ORB umbilical was directed at the outboard side of the +Y ET/SRB vertical strut. Water directed at the LH2 ET/ORB umbilical appeared to impinge the LH2 feedline area (OTV 009, E-5, -6).

Heat from SSME ignition/shutdown caused frost to melt on the ET nosecone louver and adjacent TPS serrations. After the heat wave passed, frost formed again in the cold serrations (OTV 061).

No dark spots of residue/discoloration from the GOX vent seal, like those aft of the External Tank nosecone southwest louver, occurred at the northeast louver.

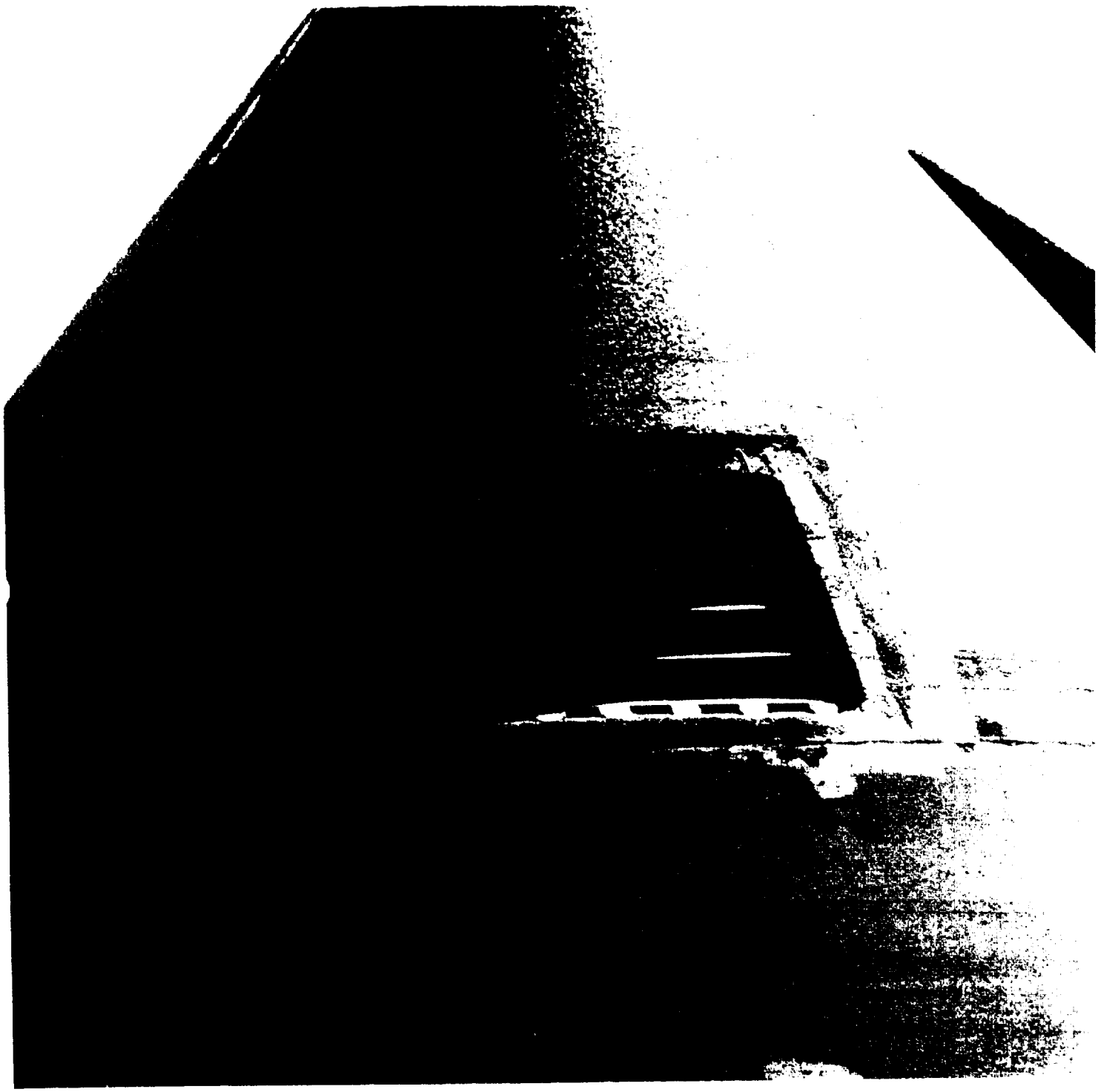

Photo 5 : Dark Residue on ET Nosecone Footprint Area

Photo 6 : LH2 Feedline and Recirculation Line TPS Erosion

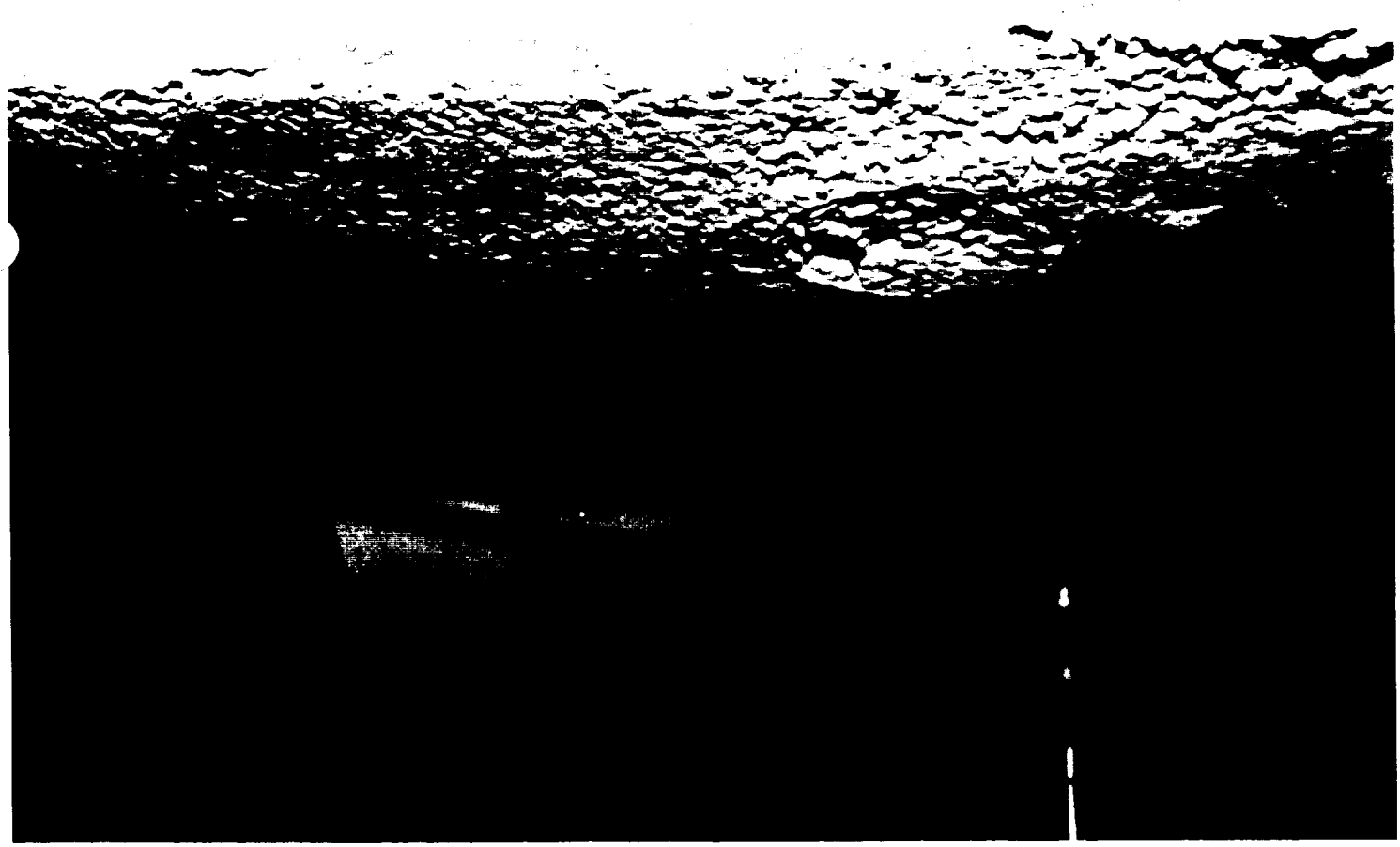

Photo 7 : +Y ET/SRB Vertical Strut TPS Erosion

3.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 29 September 1994 at 0830 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC Chief, ET/SRB Mechanical Systems Branch
G. Katnik	NASA - KSC Lead, Shuttle Ice/Debris Systems
B. Davis	NASA - KSC Digital Imaging Systems
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W. Richards	LSOC - SPC ET Mechanical Systems
R. Seale	LSOC - SPC ET Mechanical Systems
M. Wollam	LSOC - SPC ET Mechanical Systems
Z. Byrns	NASA - KSC Level II Integration
J. Stone	Rockwell Dny Aerodynamics, Debris Assessment
K. Mayer	Rockwell LSS Systems Integration
M. Nowling	MTI - LSS SRM Processing
S. Otto	MMMSS- LSS ET Processing
K. Ely	MMMSS- LSS ET Processing
H. Bowman	LSOC - SPC Safety

4.0 LAUNCH

STS-68 was launched at 11:16:00.011 GMT (7:16 a.m. local) on 30 September 1994.

4.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on September 29, 1994 from 1630 to 1800 hours. The detailed walkdown of Pad 39A and MLP-1 also included the primary flight elements OV-105 Endeavour (7th flight), ET-65 (LWT 58), and BI-067 SRB's. There were no significant facility debris issues.

A blue nylon strap with a velcro fastener typically used to secure tygon tubes was wrapped around the ET EO-3 fitting. The strap should have been removed when leak testing at the LO2 ET/ORB umbilical was completed. A lost-and-found PR was dispositioned by MPS to remove the strap prior to RSS rotation.

A small flexible debris object, most likely a piece of tape, lay on the ET crossbeam near the Orbiter lower surface tiles. Due to the location and lack of access, the object could not be removed. Debris assessment found no threat to the Orbiter and the object was deemed no constraint to launch.

4.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 30 September 1994 from 0130 to 0235 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. One facility IPR was taken. Due to the ambient weather conditions at this time of year, there were no acreage icing concerns. There were also no protuberance icing conditions outside of the established data base.

Ambient weather conditions at the time of the inspection were:

	T-3 Hours	T-0 Launch
Wind Speed (knots):	06	10
Wind Direction (degrees):	087	071
Relative Humidity (percent):	75	71
Temperature (degrees F):	80	80
Dew Point (degrees F):	71	70

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to scan the vehicle for unusual temperature gradients, particularly those areas not visible from remote fixed scanners, and to obtain a random sampling of vehicle surface temperature measurements to thermally characterize the vehicle.

4.3 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers were intact and dry. Less than usual ice/frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. An unusually large ice/frost formation, measuring 10-inches by 5-inches, was observed on the SSME #3 (ME 2026) outboard (+Y) drain line exit on both exterior and interior surfaces of the nozzle. Liquid oxygen falling from the drain line reached the brick surface of the SSME flame trench before vaporizing. Ice Team and MPS engineers assessed the presence of the ice and determined no SSME anomaly existed. The ice was not a debris threat to the vehicle and not a constraint for launch. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. Condensate was present on base heat shield tiles near SSME #2 and along the body flap hinge area.

4.4 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the fixed STI radiometers ranged from 78 to 79 degrees F. In comparison, temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 80 to 83 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 78 degrees F, which was within the required range of 44-86 degrees F.

4.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Final Inspection Team observed moderate amounts of condensate, but no ice or frost accumulations, on the LO2 tank. There were no TPS anomalies.

The intertank acreage exhibited no TPS anomalies. Typical ice/frost accumulation, but no unusual vapor, was present on the ET umbilical carrier plate.

There were no LH2 tank TPS acreage anomalies. Moderate amounts of condensate, but no ice/frost accumulations, were present on the acreage.

There were no anomalies on the bipod jack pad closeouts. A crack, 10-inches long by 3/8-inch wide, was present in the -Y ET/SRB cable tray forward surface TPS. The presence of the crack was acceptable for flight per the NSTS-08303 criteria.

One spot frost spot appeared on the -Y longeron closeout and on the -Z side of the +Z manhole cover closeout. A small flexible debris object, which lay on the forward surface of the ET crossbeam and assessed as no debris threat to the Orbiter during the Pre-Launch Walkdown, was still in the same location at the time of the Final Inspection.

All repairs to the ET TPS areas damaged by the Firex water spray during the abort were intact and showed no ice or frost formations.

Typical amounts of ice/frost had accumulated in the LO2 feedline bellows while less than usual amounts of ice/frost appeared in the support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were filled with ice and frost. One small frost spot had formed on the aft surface of the feedline.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. The 17-inch flapper valve actuator access port foam plug was properly closed out, though light frost had formed on the aft corner of the closeout. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The summary of Ice Team observations/anomalies, which were all acceptable for launch per the NSTS-08303 criteria, consisted of five OTV recorded items:

Anomaly 001 documented ice/frost formations in the LO2 feedline support brackets and bellows.

Anomaly 002 documented a 3-foot nylon rope with cloth safety sign on the OWP/FSS walkway FSS 135 foot level (IPR 68V-0140).

Anomaly 003 documented a 10-inch by 3/8-inch crack in the forward surface TPS of the -Y vertical strut/ET-SRB cable tray.

Anomaly 004 documented 2-inch by 1-inch ice/frost formations on both +Y and -Y longeron closeout edges.

Anomaly 005 documented ice/frost formations on the LO2 ET/ORB umbilical purge vents and the LH2 ET/ORB umbilical purge vents, recirculation line bellows, and purge barrier.

4.6 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement).

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, the GH2 vent line, or the GUCP.

No damage to the ET nosecone/footprint area was visible after the GOX vent hood was retracted.

A 3-foot nylon rope with cloth safety sign on the OWP/FSS walkway (FSS 135 foot level) could not be reached by the Final Inspection Team. IPR 68V-0140 was taken and dispositioned with a no constraint to launch rationale. The vehicle was shielded from the rope and sign by the -Y OWP curtain. The SRB exhaust plume would not affect the rope until the vehicle cleared the tower.

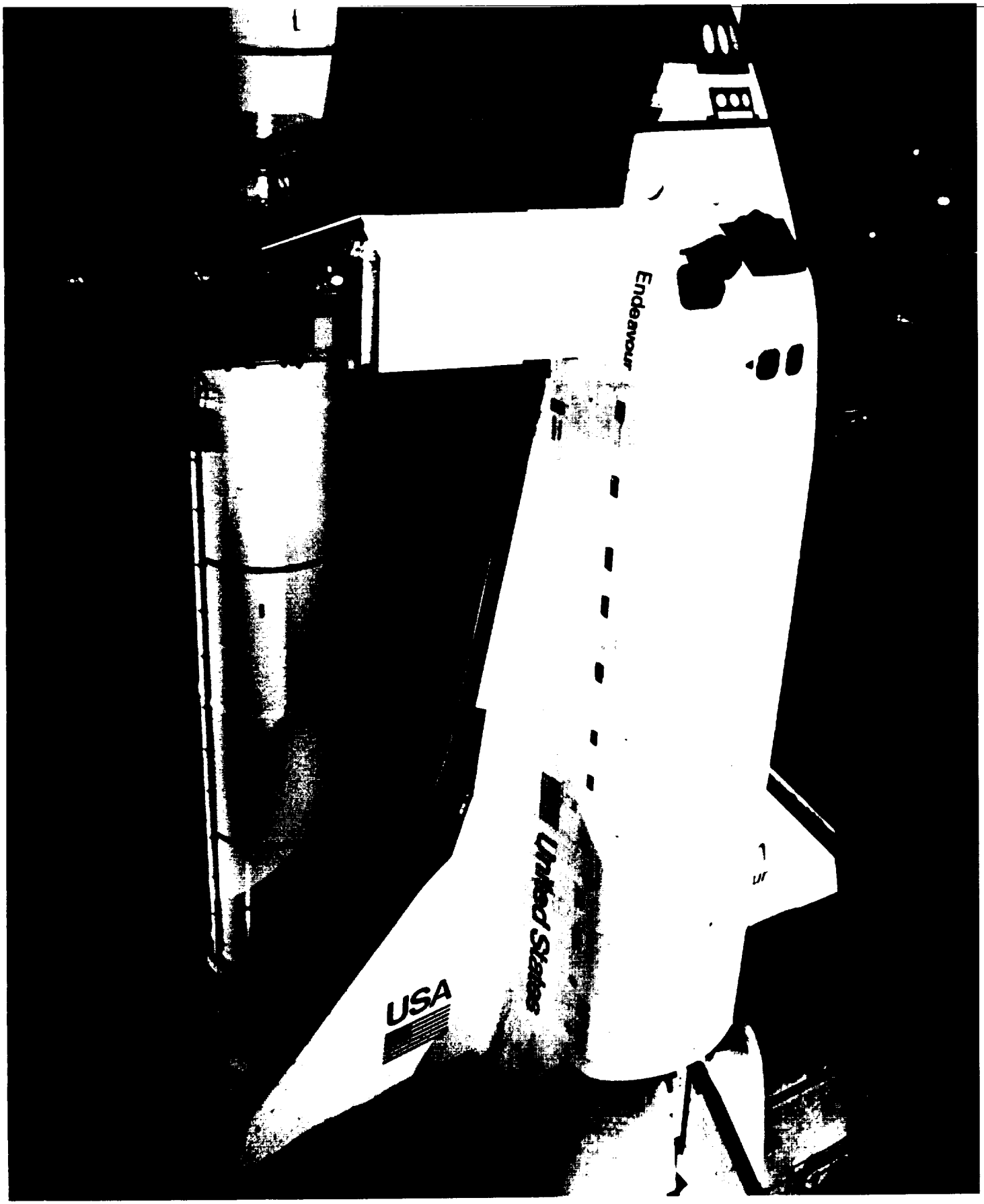


Photo 8 : Overall View of STS-68 Vehicle

OV-105 Endeavour (7th flight), ET-65 (LWT 58), and BI-067 SRB's

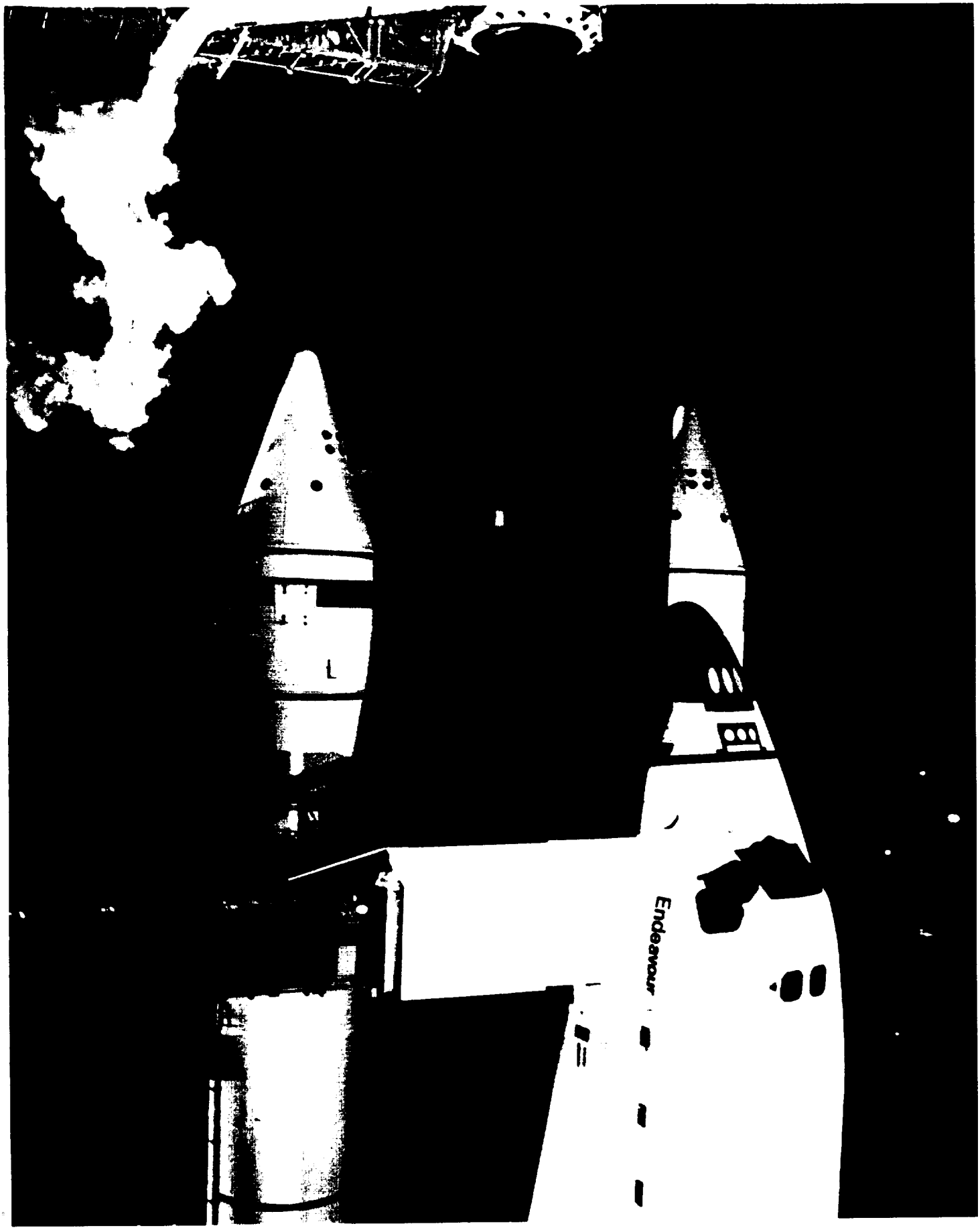


Photo 9 : No Ice or TPS Anomalies on External Tank Acreage

Photo 10 : Large Ice Buildup on SSME #3 Drain Line

Unusually large ice/frost formation on SSME #3 outboard (+Y) drain line extended 12 inches in the -Z direction along the nozzle exit

Photo 11 : Large Ice Formation on SSME #3 Outboard Side

Liquid oxygen drips fell from drain line to bottom of flame trench before vaporizing

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the Pad 39A, MLP, FSS and RSS was conducted on 30 September 1994 from 2 to 3.5 hours after launch.

No flight hardware or TPS materials were found.

South SRB HDP erosion was typical. All south HDP shoe EPON shim material was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was normal with the exception of missing material on several southern corners. The SRB aft skirt purge lines and T-0 umbilicals exhibited typical exhaust plume damage.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA), and GOX vent arm appeared undamaged.

At the time of the walkdown, the LH2 TSM door was closed and external surfaces showed no signs of damage. Launch films showed the door remained open as the SSME's passed by during liftoff (PR PV-6-274767). Post launch data revealed the door stayed open until T+7 seconds MET. Evidence of flame intrusion and exhaust plume impingement inside the TSM was discovered during the post launch inspection. The door did not close properly due to the structural failure of brackets holding the bonnet safety pin guide tube (middle support bracket broken prior to launch and rusted front bracket broken during ignition). This condition caused the guide tube to move and break the rear bracket. The resulting misalignment prevented the retraction of the pyro pin. The PR was closed by repairing or replacing any guide tube support brackets in all TSM's.

The GH2 vent line was latched on the seventh tooth of the latching mechanism, had no loose cables (static retract lanyard), and appeared to have latched properly with no rebound. Vent line insulation was torn and missing on the FSS.

Minor, but typical, pad damage included:

Numerous pieces of thin glass were found on the MLP west side presumably from the pad stadium lights.

'CAUTION' sign was missing from OWP access arm (135 foot level), identified during T-3 walkdown.

Open OIS panel doors on the 215' & 255' levels.

Cable tray cover on pad apron west of FSS.

15 foot section of SSME flame trench east side upper edge was torn loose and located in pieces along the east crawlerway.

The pad cooling tower was leaking and a valve was hit by some debris, which broke the valve stem off above the hand wheel.

Debris inspections of the pad acreage and flame trench were completed. No flight hardware or TPS material was found.

Post launch pad inspection anomalies are listed in Section 10.

Photo 12 : North Holddown Post Blast Cover Erosion

6.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or In-Flight Anomalies were generated as a result of the film review. Post flight anomalies are listed in Section 10.

6.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 98 films and videos, which included thirty-eight 16mm films, nineteen 35mm films, four 70mm films, and thirty-seven videos, were reviewed starting on launch day.

No vehicle damage or lost flight hardware was observed that would have affected the mission.

Dark carbon-type residue from the GOX seals was present again on the ET nosecone after the GOX vent hood was retracted (OTV 062).

Free burning, green tinted hydrogen from SSME startup drifted past SSME #1 in the general direction of the LH OMS pod (OTV 070, 071).

Fore-and-aft movement of the Orbiter base heat shield in the centerline area between the SSME cluster occurred during engine start-up. The motion was similar to that observed on previous launches (E-76, -77).

SSME ignition, Mach diamond formation, and gimbal profile appeared normal. Three streaks occurred in the SSME #1 plume during startup (E-2). The unusually large ice/frost formation on the SSME #3 drain line (reported during the Final Inspection at T-3 hours) was not visible at liftoff and most likely fell aft during startup (OTV 051, 070, 071).

SSME ignition caused a tile gap filler to protrude from the lower surface of the left inboard elevon. The gap filler was still protruding from a location close to the elevon hinge near the Orbiter aft fuselage as the vehicle left the field of view (OTV 009, 063, 064; E-31).

SSME ignition caused numerous pieces of ice to fall from the ET/Orbiter umbilicals. Some pieces of ice contacted the umbilical cavity sill and were deflected outward, but no tile damage was visible (OTV 009, 063).

The ET "twanged" approximately 31 inches before returning to the 12 inch mark at liftoff (E-79).

No stud hang-ups occurred on any of the holddown posts. No ordnance fragments or frangible nut pieces fell from any of the DCS/stud holes. All north holddown posts doghouse blast covers closed normally.

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (E-17, -18). However, the LH2 TSM bonnet door remained open after the SSME's had passed the top of the TSM (E-1, -2, -5, -19, -25). The cause of the anomaly is described in Section 5.0. A small object, possibly a pin or short cable, fell from the LH2 TSM external access platform and fell aft without contacting the vehicle (E-18).

GUCP disconnect from the External Tank was nominal. Small ice particles, but no TPS, fell from the interface area after disconnect (E-33). The GH2 vent line appeared to latch normally (OTV 004, 060; E-41, -42, -48, -50). Post launch inspection found the GH2 vent line latched on the seventh tooth of the latching mechanism.

Ice from the ET/SRB diagonal and aft struts fell aft shortly after T-0 and impacted the LH SRB aft skirt without causing any damage (E-57).

Large light-colored pieces of SRB throat plug moved north and upward out of the SRB flame trench away from the vehicle after liftoff. Large pieces of ET/ORB LH2 umbilical ice continued to fall during early ascent (TV-4A, E-63).

A white object, most likely a piece of SRB propellant or aft skirt instafoam, dropped out of the RH SRB plume at 11:16:23.906 GMT (E-59). Numerous particles fell out of the SRB plume during ascent and were most likely small chunks of propellant. One noticeably large piece was visible at 11:16:26.375 GMT (E-52, -57).

Two white vapor-like streaks, or trails, streamed past the RH OMS pod and crossed the SSME plume at T+36 seconds MET (E-207, -222, -223, -224). Deep tile damage observed on the RH OMS pod leading edge tiles in orbit by the flight crew was most likely the result of a debris impact manifesting itself as the two white vapor trails, which may have been pulverized tile material.

Two white objects, probably RCS paper covers, first became visible in the area of the vertical stabilizer falling aft at 11:16:36.148 GMT. Several more white particles, most likely FRCS paper covers, passed the RH OMS pod in this same time frame. However, RCS paper covers tend to cause shallow tile damage sites rather than the deep damage observed on the RH OMS pod.

Two small white objects were visible just forward of the vertical stabilizer moving aft at 11:16:43.661 GMT. White wispy vapor was observed aft of the OMS pod/vertical stabilizer at 11:16:43.761. A third white object was first visible near the base of the vertical stabilizer falling aft at 11:16:44.033 GMT. The white objects appeared to originate from the Orbiter nose area and are most likely FRCS paper covers. One of these covers may have contacted the leading edge of the vertical stabilizer and disintegrated into very small pieces giving the appearance of a vapor trail (TV-4A; E-223, -224). Shallow tile damage observed on the vertical stabilizer leading edge during the post landing inspection may have been caused by FRCS paper cover impacts.

All SSME Dome Mounted Heat Shield closeout blankets appeared to be intact and missing no material (E-207).

Several flashes occurred in the SSME plume during ascent (E-205, -218).

Body flap movement (amplitude and frequency) was similar to previous flights (E-207, -213).

Numerous small pieces of SRB propellant fell out of the plume during ascent - a typical occurrence (E-212).

Exhaust plume recirculation and ET aft dome outgassing/charring was typical. SRB plume tailoff and separation appeared normal. Slag was visible in the SRB plumes during and after separation (TV-5, -13; E-207, -208, -212, -220).

Photo 13 : Open LH2 TSM Door at Liftoff

Photo 14 : LH2 TSM Door Remained Open Until T+7 Seconds

Photo 15 : Vapor-Like Streaks Past RH OMS Pod

Since localized condensation collars were not present on other parts of the vehicle, vapor trails streaming aft of the RH OMS pod are believed to be related to the debris impact that damaged the OMS pod leading edge tile rather than any type of atmospheric phenomenon. The actual debris impact was not visible in the film due to the lighting conditions.

6.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew. Hand-held video footage and thirty-eight still images were obtained of the ET after separation from the Orbiter. OV-105 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; 35mm still views. Data was obtained from all sources. In addition, images of streaks on the forward facing windows, the missing perimeter tile from window #8, and damage to the RH OMS pod leading edge tile were downlinked during the mission.

No vehicle damage or lost flight hardware was observed that would have been a safety of flight concern. No material was missing from the forward part of the External Tank (LO2 tank and nosecone) that could have caused the damage to the Orbiter RH OMS pod tiles.

SRB separation from the External Tank was nominal. A dark object, most likely a piece of charred foam, fell aft from an area behind the LH2 ET/ORB umbilical cable tray.

ET separation from the Orbiter was nominal. The BSM burn scars on the LO2 tank were typical. No anomalies were apparent on the nosecone, LO2 tank acreage, PAL ramps, RSS antennae, flight door, bipod ramps, LO2 feed line, and aft hard point. Erosion of the manhole cover closeouts and aft dome apex was also typical. A flat, thin, 5-inch diameter piece of foam tumbled aft past the -Y thrust strut after ET separation. The piece of foam may have originated from the divot in the LH2 tank acreage or the LH2 tank-to-intertank flange closeout +Y+Z quadrant.

Foam, approximately 12 inches in length by 4 inches wide, was missing from an intertank stringer head at XT-1050 forward of the bipods and to the -Y side of centerline. The divot exposed the substrate. Less than usual shallow "popcorn" type divots were visible in stringer valleys on the +Z intertank acreage forward of the bipods.

Both bipod jack pad closeouts were intact and appeared to be in excellent condition.

A divot, approximately 5 inches in diameter but shallow in depth, occurred in the LH2 tank acreage aft of the LH2 tank-to-intertank flange closeout between the -Y thrust panel and the -Y bipod spindle housing closeout.

Two divots, 10 to 12 inches in diameter, were present in the intertank acreage/stringers adjacent to and into the LH2 tank-to-intertank flange closeout on the -Z side of the tank between the RSS antenna and -Z intertank vent. A third divot, approximately 8 to 10 inches in diameter, occurred in the LH2 tank-to-intertank flange closeout aft of the flight umbilical carrier plate area. A fourth divot approximately 6 inches in diameter was visible in the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant on the +Y side of the LO2 feedline.

The +Y thrust strut and LO2 feedline flange foam closeouts exhibited minor erosion.

The LH2 ET/ORB umbilical appeared to be in good condition with no observed TPS damage. The red purge seal was intact. Blistering of the fire barrier coating was typical. Frozen hydrogen had dislodged from the 17-inch flapper valve but was still attached to the disconnect. Foam was missing or eroded from the horizontal section of the cable tray, the LH2 feedline outboard support bracket, and the aft surface of the -Y vertical strut.

Likewise, no TPS damage was observed on the LO2 ET/ORB umbilical. Numerous divots and eroded areas were visible on the horizontal section of the cable tray. Dark shadow prevented examination of the red purge seal and the lightning contact strips.

KSC reviewed the downlinked imagery of the window streaks and RH OMS pod tile damage during the mission.

The window streaks were similar in size and appearance to streaks/deposits left by FRCS paper covers and RTV bonding material documented photographically on previous flights. This was an expected occurrence.

Images of the RH OMS pod leading edge tiles showed a deep damage site (5-inches by 3-inches by 2-inches to substrate) indicative of an impact by a dense particle. A debris impact in this area could not be discerned due to the lighting conditions and atmospheric haze affecting the tracking films. However, the two white vapor-like streaks passing the RH OMS pod at T+36 seconds MET may have been pulverized tile material.

Photo 16 : Nominal SRB Separation from External Tank

Charring of vertical strut aft surface TPS and erosion of LH2 ET/ORB umbilical cable tray TPS was typical

Photo 17 : Nominal ET Separation from Orbiter

No damage to ET/ORB umbilical TPS was visible. Large piece of frozen hydrogen was loose but still attached to the 17-inch feedline flapper valve.

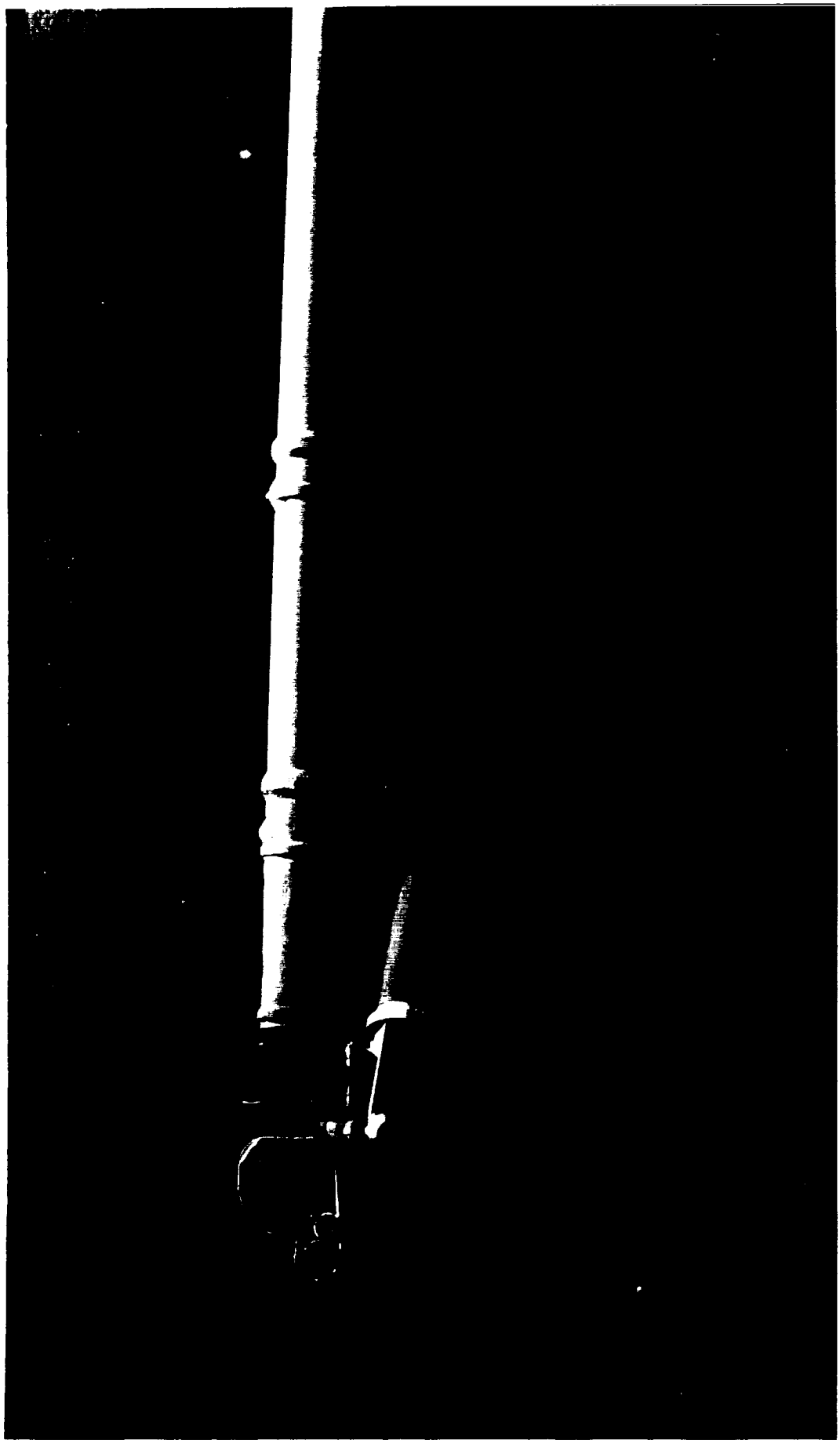


Photo 18 : View of LO2 ET/ORB Umbilical and Feedline

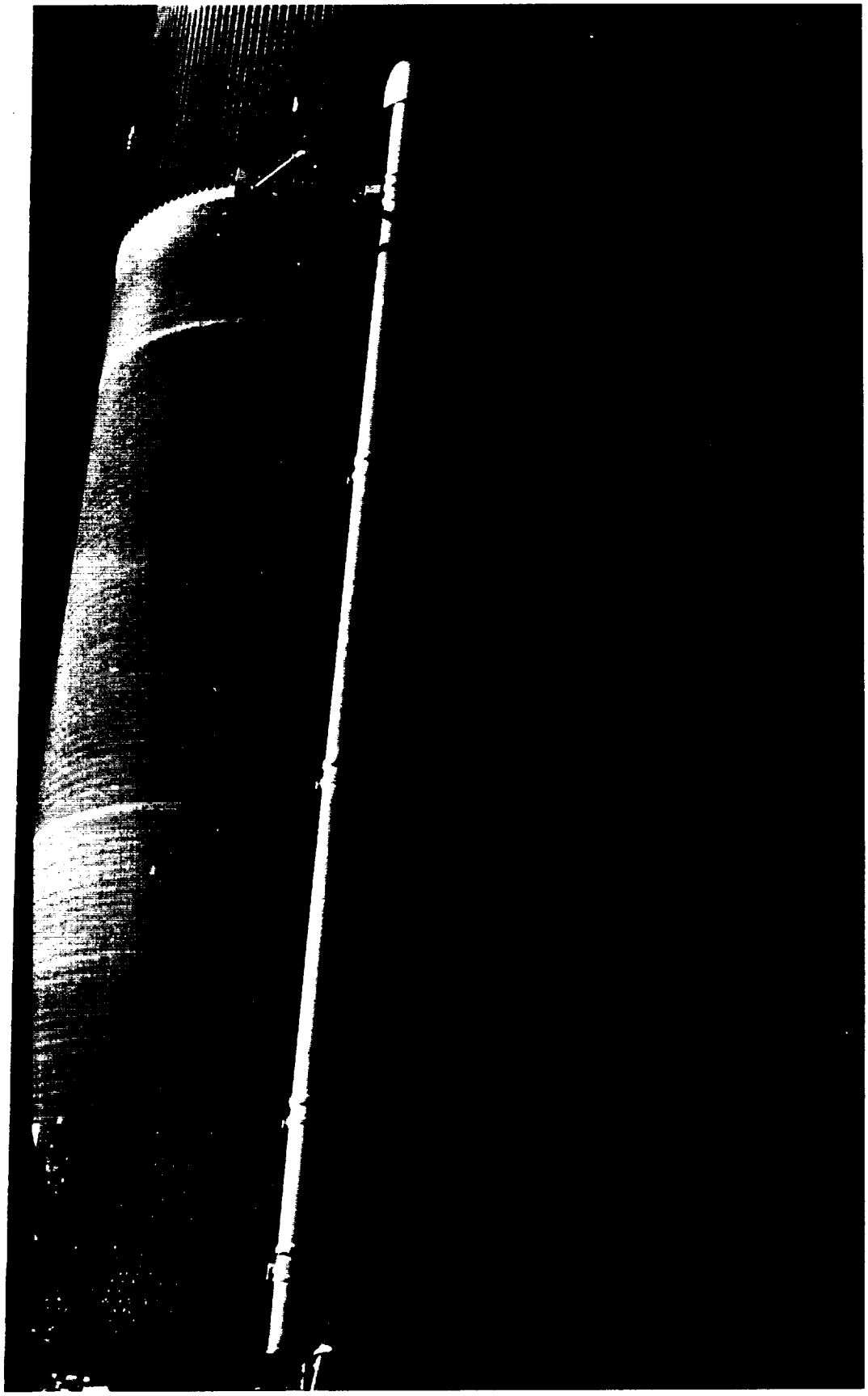


Photo 19 : View of Jack Pad Closeouts and +Z Acreage

Foam, approximately 10 inches in length, was missing from an intertank stringer head at XT-1050 forward of the bipods. The divot exposed the substrate. The bipod jack pad closeouts were intact and appeared to be in excellent condition.

Photo 20 : View of Nosecone and -Y Acreage

No TPS damage was visible on the nosecone. BSM burn scar on the LO2 tank acreage was typical. Note 8-10 inch divot at LH2 tank-to-intertank flange closeout aft of flight umbilical carrier plate area.

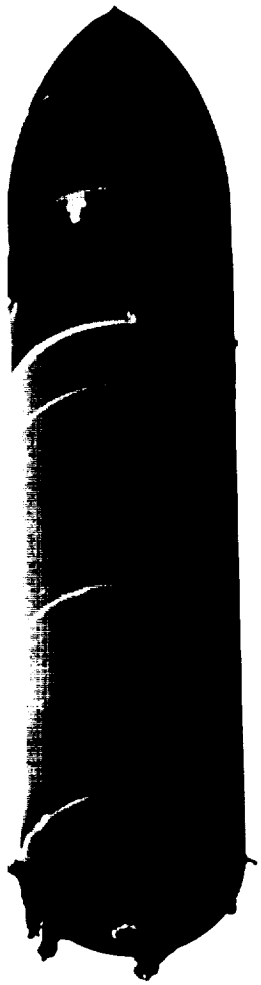


Photo 21 : View of Aft Dome and -Z Acreage

LO2 tank, LH2 tank, and aft dome TPS acreage were in good condition with no apparent anomalies. Charring of aft dome and erosion of manhole cover TPS closeouts was typical. Note two divots in intertank stringer head TPS at the LH2 tank-to-intertank flange closeout area.

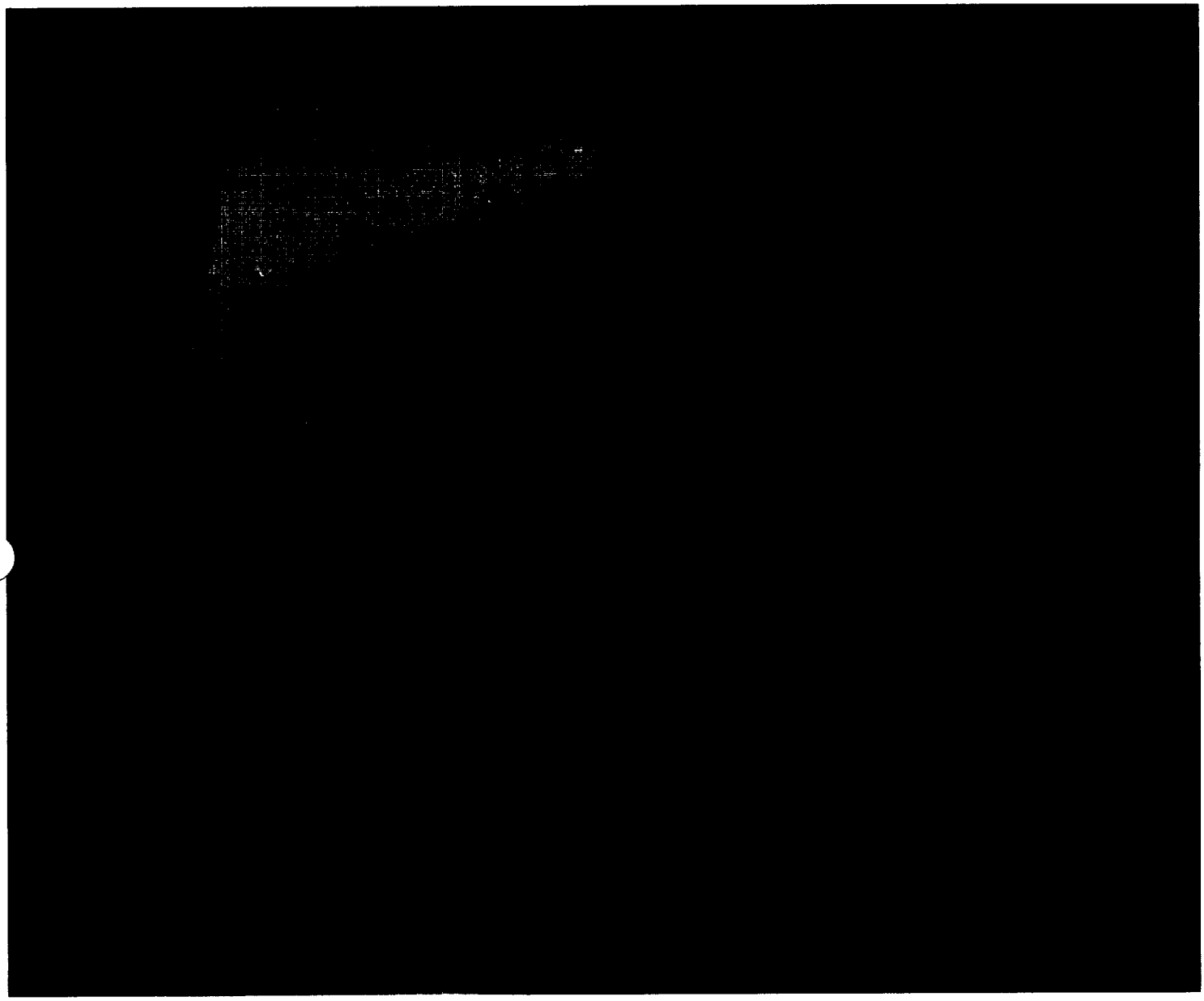


Photo 22 : Streaks and Residue on Forward Facing Window

The window streaks were similar in size and appearance to streaks/deposits left by FRCS paper covers and RTV bonding material documented photographically on previous flights.

Photo 23 : On-Orbit View of RH OMS Pod Tile Damage

Image taken by the flight crew of the RH OMS pod leading edge tiles showed a deep damage site (5-inches by 3-inches by 2-inches to substrate) indicative of an impact by a dense particle

6.3 LANDING FILM AND VIDEO SUMMARY

Eight 16mm films and seven videos of landing were reviewed.

Orbiter performance on final approach appeared normal. There were no anomalies when the landing gear was extended. Touchdown of the left and right main gear was nominal and virtually simultaneous.

The drag chute was deployed after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal.

Touchdown of the nose landing gear was smooth. No obvious tile damage or unusual control surface deflections were observed during rollout.

7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 3 October 1994. From a debris standpoint, both SRB's were in good condition.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH nose cap was recovered. The only missing MSA-2 was the result of water impact.

The RH frustum was missing no TPS but had 26 debonds over fasteners (Figure 1). Hypalon paint was blistered/missing along the 395 ring frame where BTA had been applied. Some of the underlying BTA was sooted. The BSM aero heat shield covers had locked in the fully opened position.

The RH forward assembly exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where the BTA had been applied. No pins were missing from the frustum severance ring.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The forward stiffener ring was damaged by water impact. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring exhibited typical delamination. Aft skirt acreage TPS was generally in good condition. Hypalon paint was blistered/missing over the areas where the BTA had been applied. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

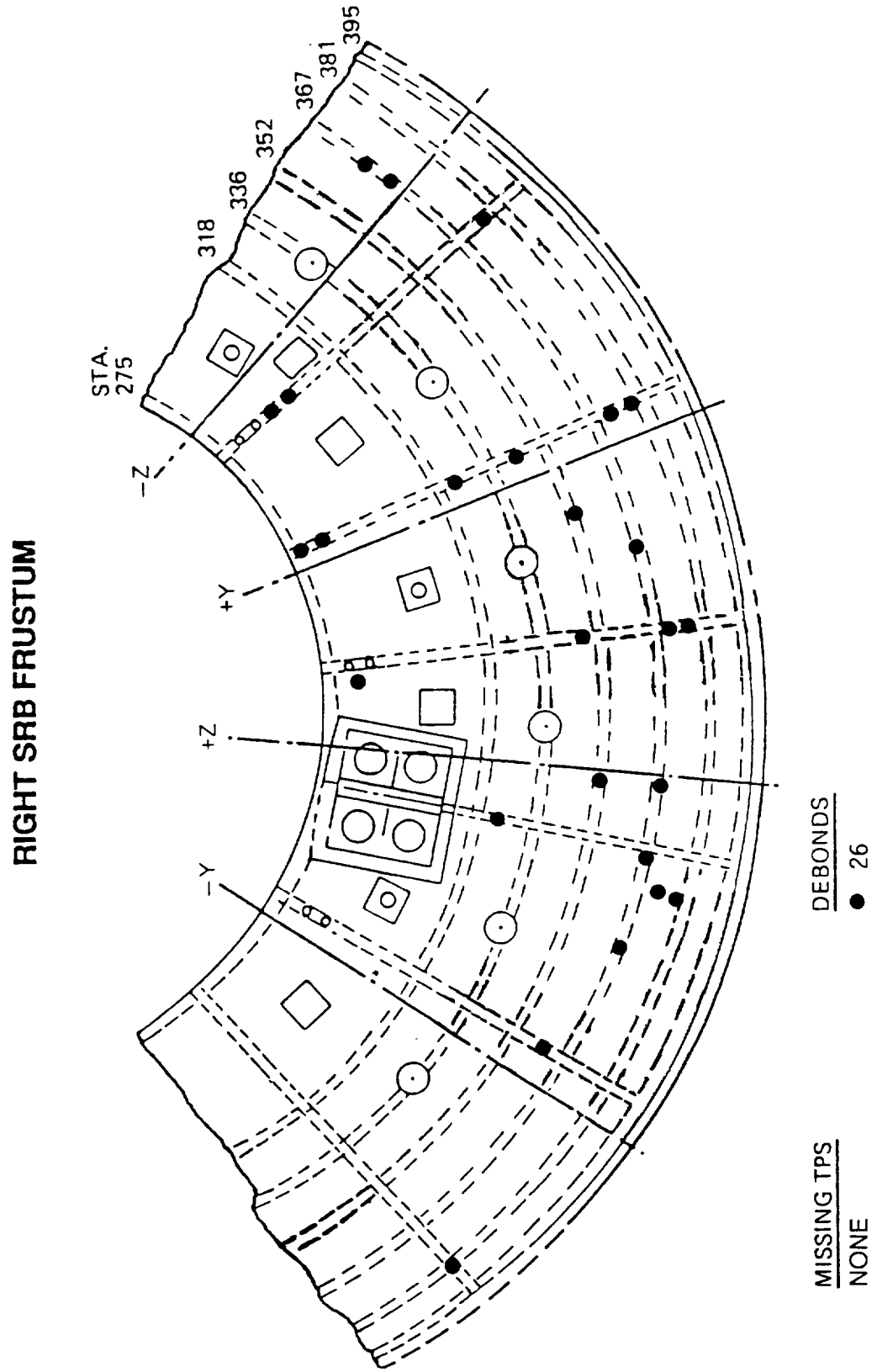


Figure 1 : RH SRB Frustum

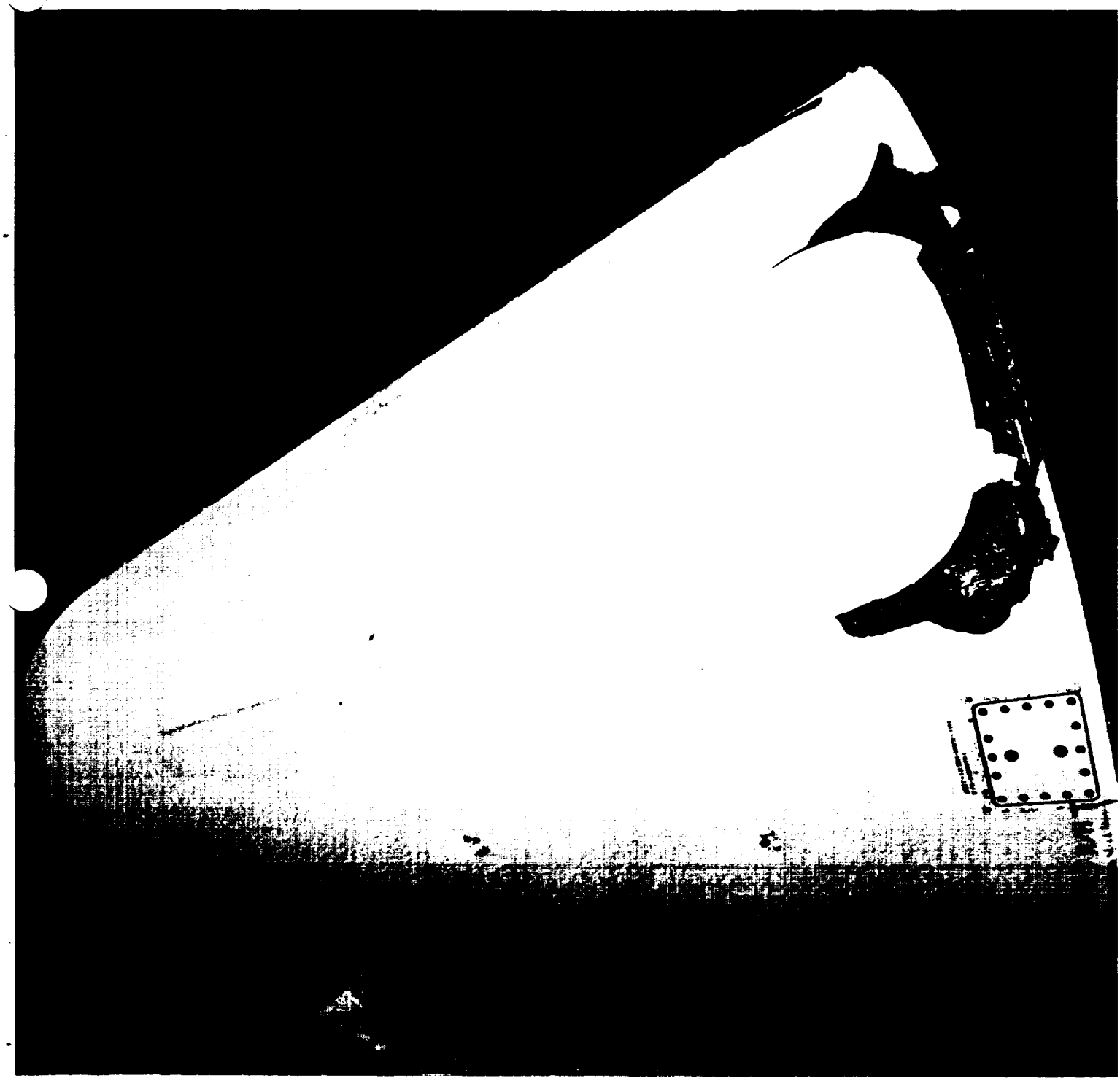


Photo 24 : RH Nose Cap

The only missing MSA-2 was the result of water impact

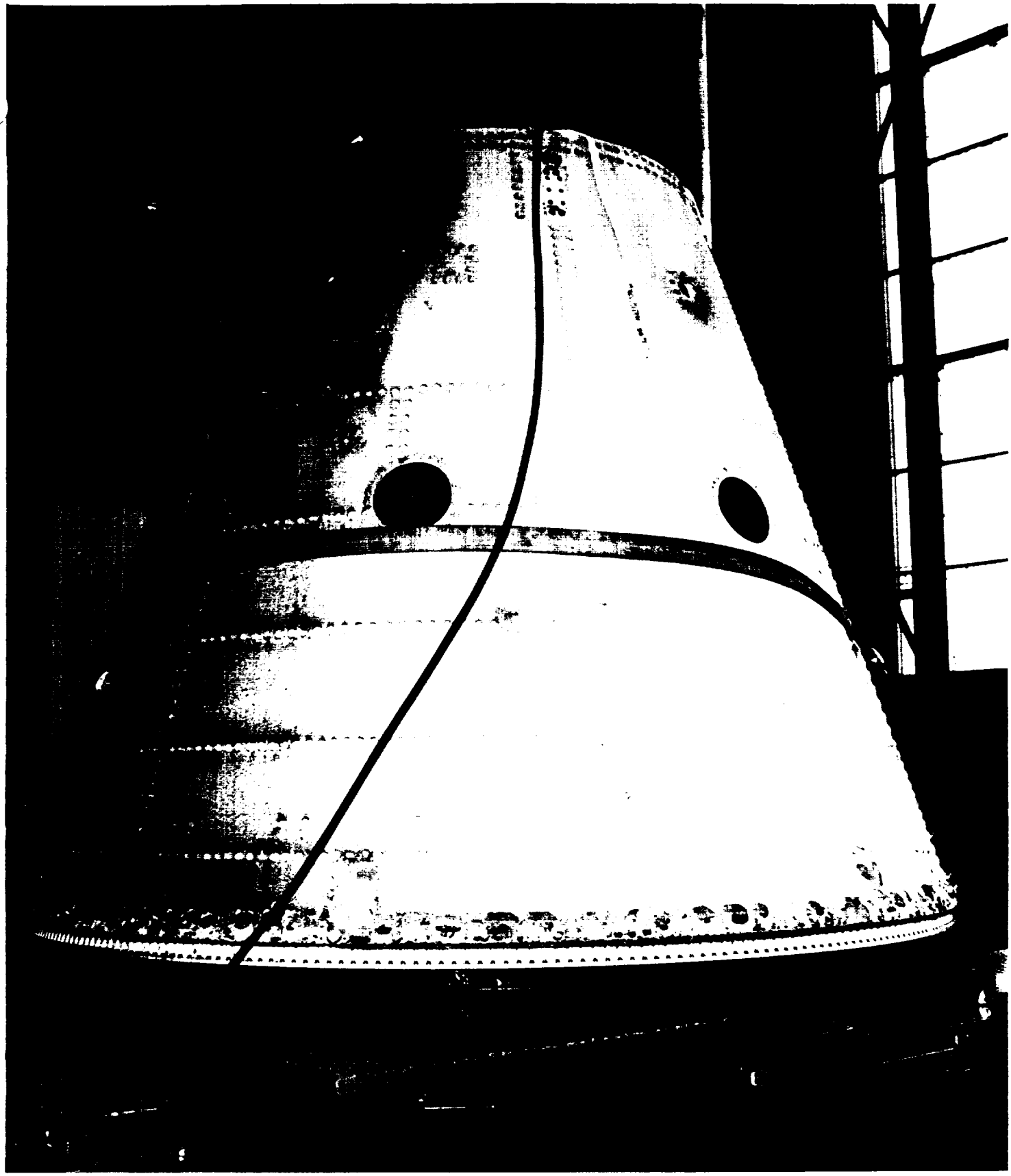


Photo 25 : RH Frustum

The RH frustum was missing no TPS but had 26 MSA-2 debonds over fasteners
The BSM aero heat shield covers had locked in the fully opened position.

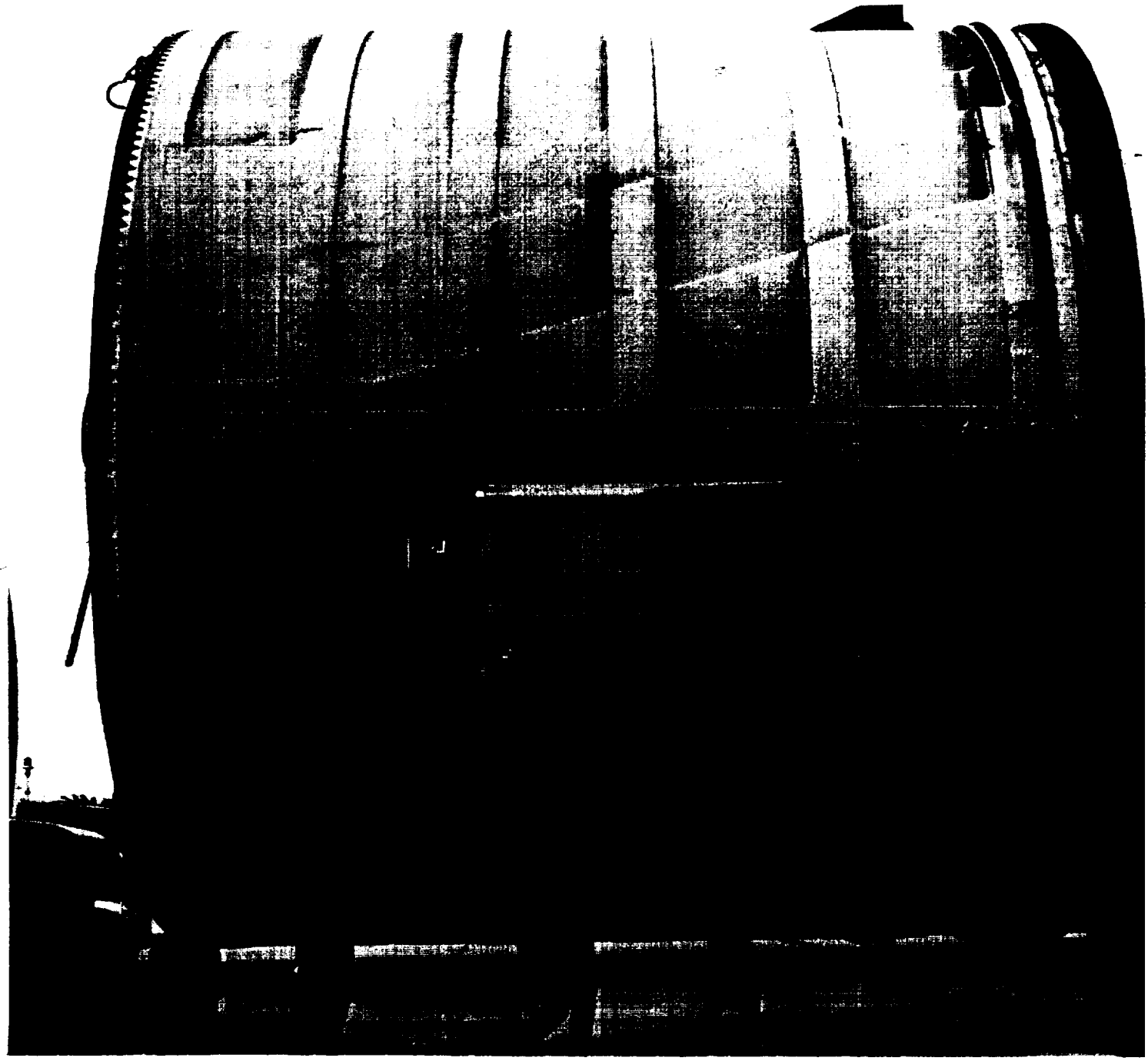


Photo 26 : RH Forward Assembly

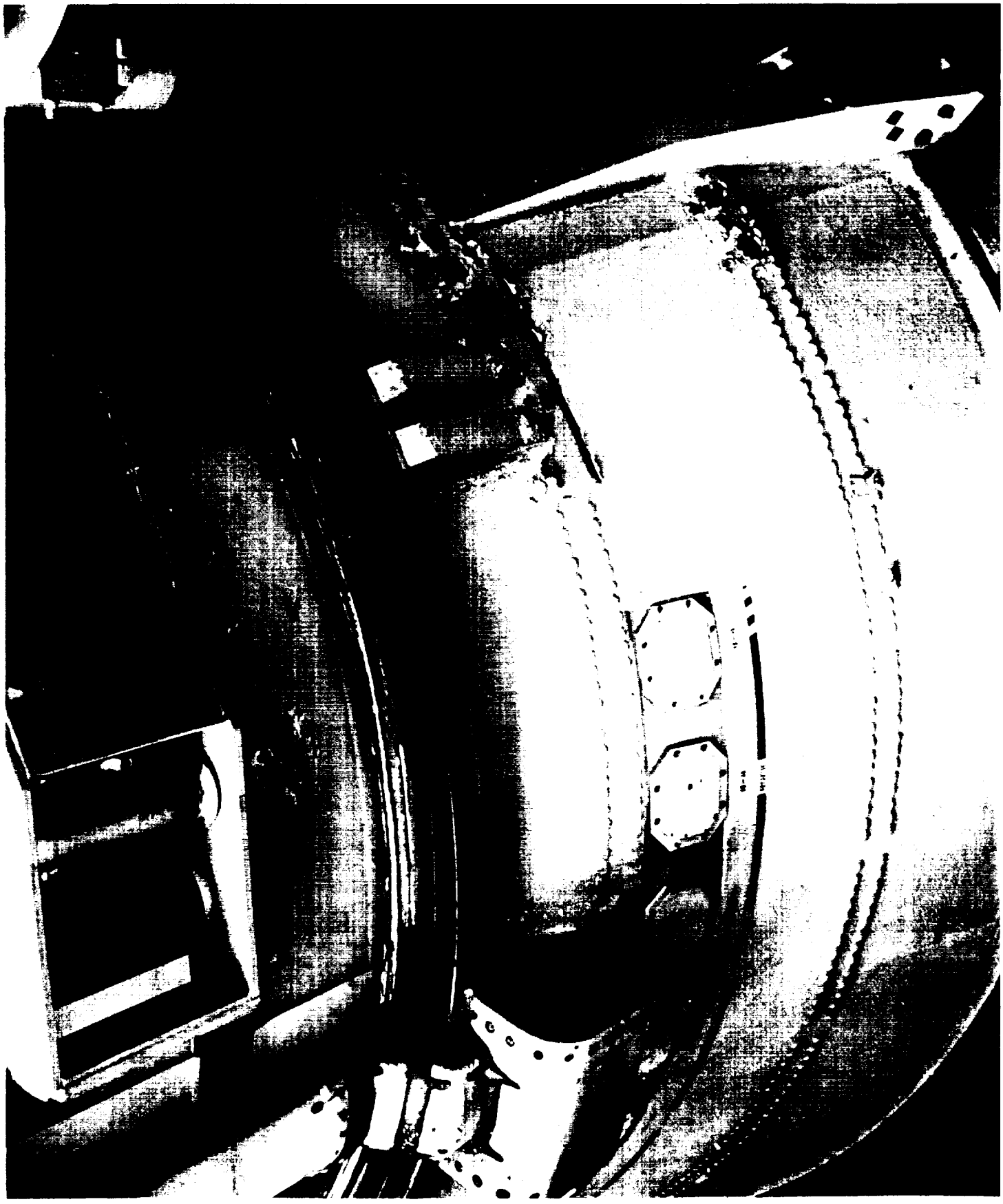


Photo 27 : RH Aft Skirt

Aft skirt acreage TPS was generally in good condition.
Hypalon paint was blistered/missing where the BTA closeouts had been applied.

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS but had 15 MSA-2 debonds over fasteners (Figure 2). Hypalon paint was blistered/missing along the 395 ring frame where BTA had been applied. Some of the underlying BTA was sooted. The BSM aero heat shield covers had locked in the fully opened position.

The LH forward assembly acreage was missing no TPS but had one debond at the XB-445 ring frame between the forward attach fitting and the flight door. Both RSS antennae covers/phenolic base plates were intact. Blistering of the Hypalon paint occurred near the ET/SRB attach point. No pins were missing from the frustum severance ring.

The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, IEA covers, and stiffener rings appeared undamaged. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring exhibited typical delamination Aft skirt acreage TPS was generally in good condition. However, a 4"x2" area of MSA-2 was missing near the XB-1894 ring frame at the +Y axis between HDP #5 and #7. A second, smaller area was located near the XB-1894 ring frame between the BSM's and the HDP #6 structure. Hypalon paint was blistered over areas where BTA had been applied. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

SRB Post Launch Anomalies are listed in Section 10.

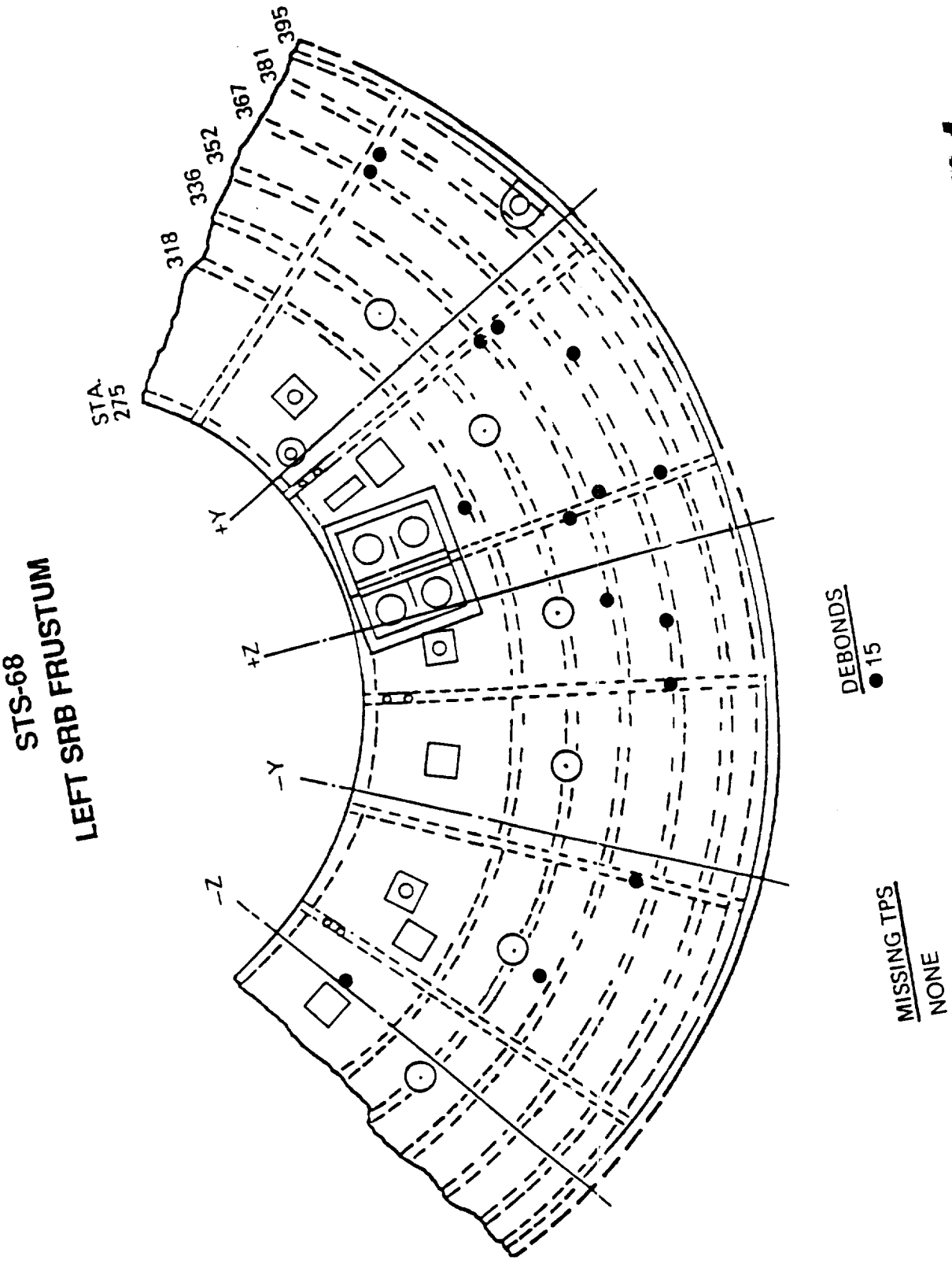


Figure 2 : LH SRB Frustum

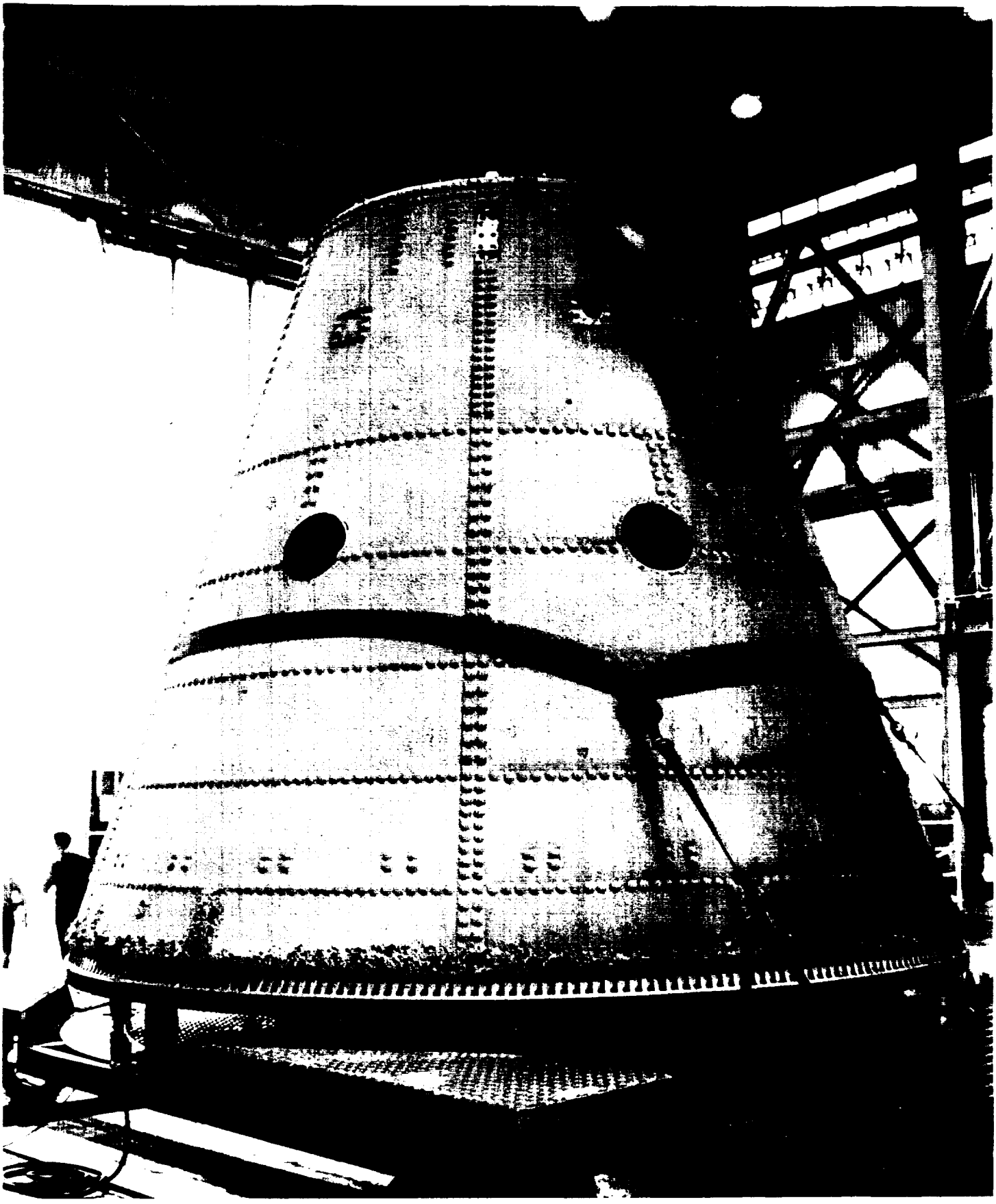


Photo 28 : LH Frustum

The LH frustum was missing no TPS but had 15 MSA-2 debonds over fasteners. Hypalon paint was blistered/missing where the BTA closeouts had been applied. All BSM aero heat shield covers had locked in the fully opened position.

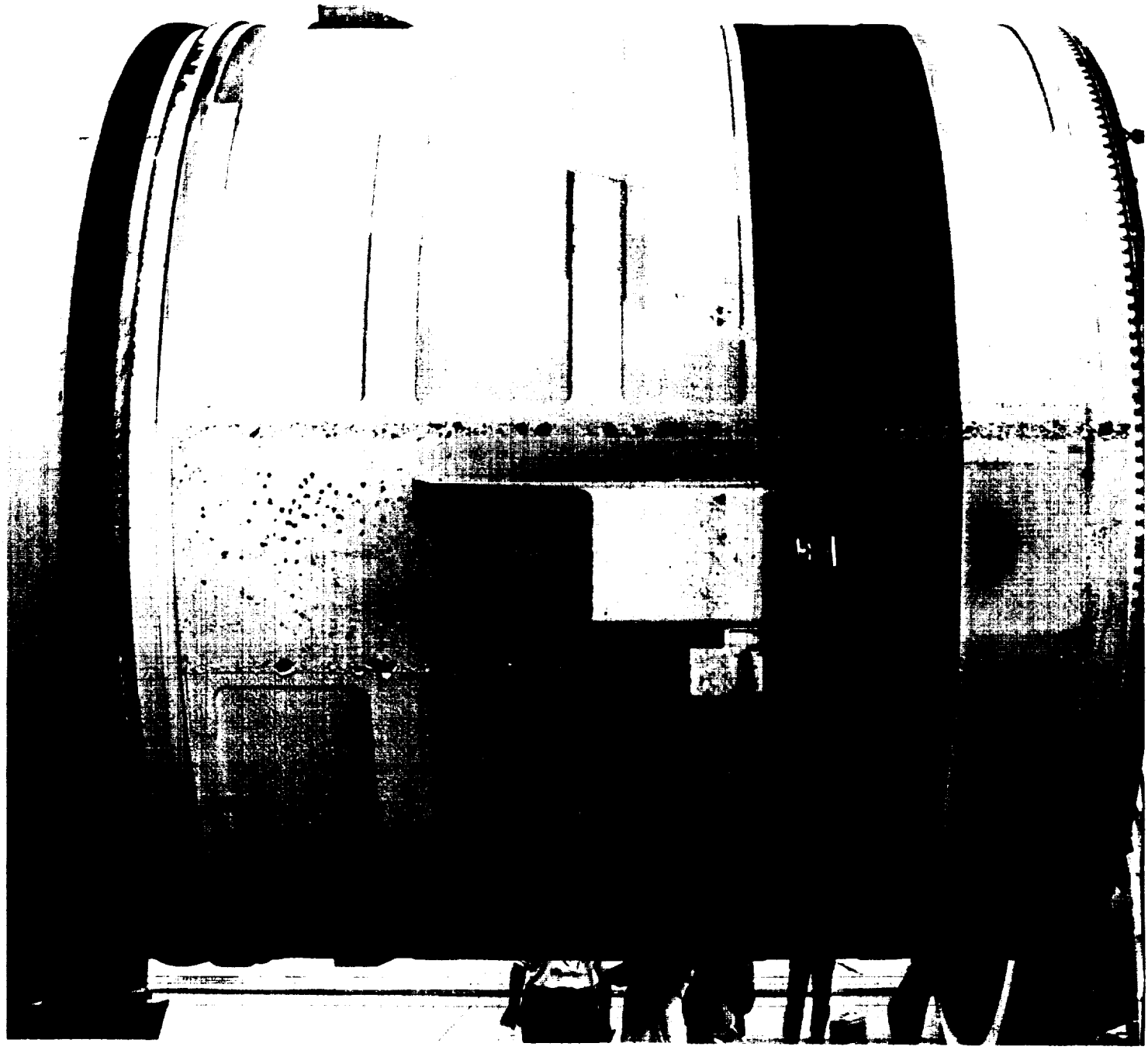


Photo 29 : LH Forward Assembly

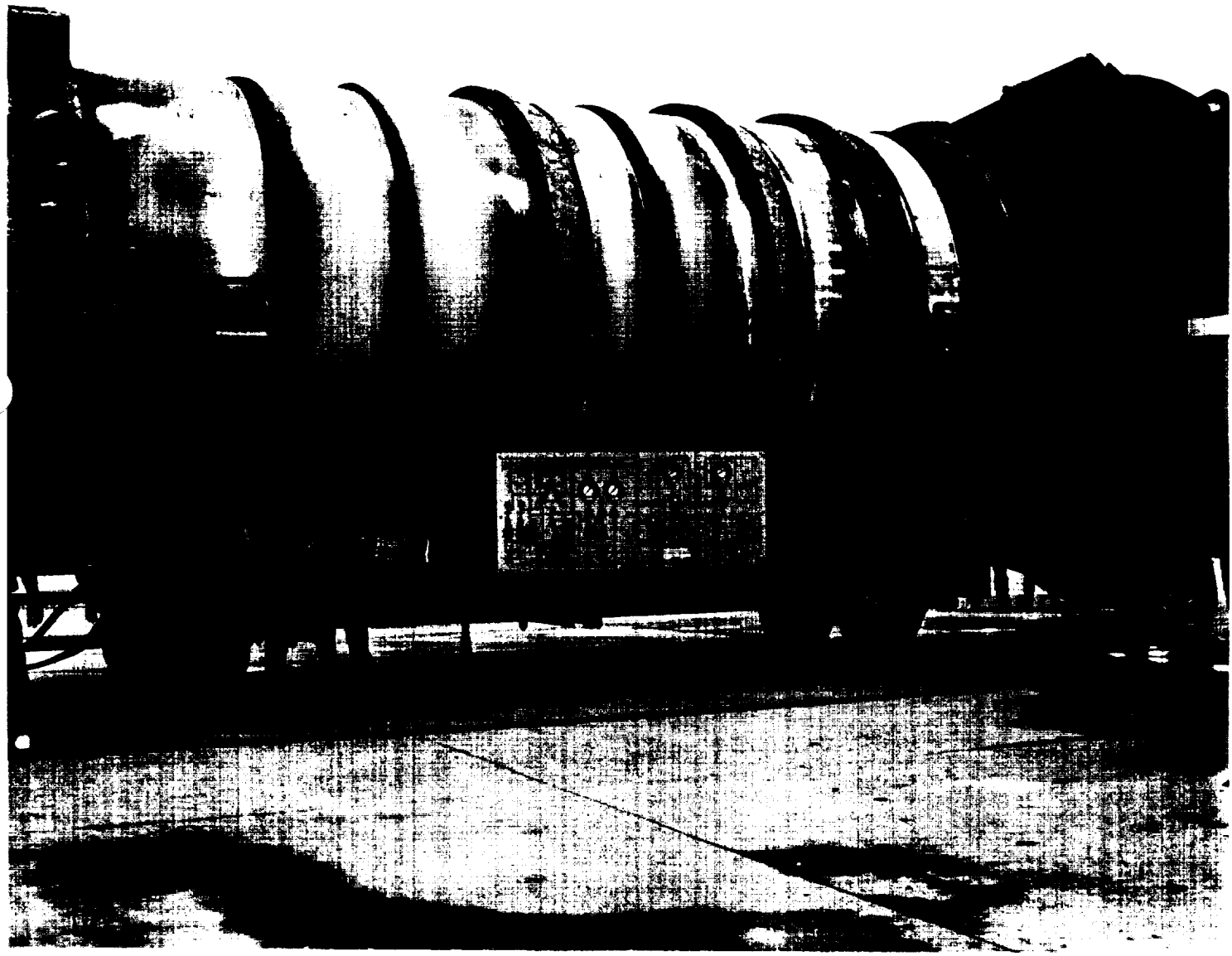


Photo 30 : LH Aft Booster/ Aft Skirt

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-105 (Endeavour) was conducted 11-13 October 1994 at the Dryden Flight Research Center/Edwards Air Force Base on Runway 22 and in the Mate/Demate Device. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 110 hits, of which 15 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 49 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits and the number of hits 1-inch or larger was slightly less than average (reference Figures 3-6).

The following table breaks down the STS-68 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	9	59
Upper surface	3	36
Right side	1	5
Left side	0	1
Right OMS Pod	2	5
Left OMS Pod	0	4
TOTALS	15	110

The Orbiter lower surface sustained a total of 59 hits, of which 9 had a major dimension of 1-inch or larger. A tile damage site with embedded debris was found just forward of the LO2 ET/ORB umbilical in tile number V070-190002-110 ET-3237. This debris was removed for material identification analysis prior to the ferry flight. Another tile damage site with embedded debris was located just aft of the nose landing gear door in tile number V070-391017-161 ET-9431. This debris was removed and identified as gap filler material by TPS Engineering.

A cluster of hits occurred just aft of the LH2 ET/ORB umbilical. Two of these damage sites had a major dimension larger than 1-inch. Cluster of hits aft of the LH2 and LO2 ET/ORB umbilicals are believed to be impacts from umbilical ice and purge barrier (baggie) material.

No tile damage from micrometeorites or on-orbit debris was identified during the inspection.

The largest tile damage site was located on the RH OMS pod forward facing surface and measured 5 inches by 5 inches by 2 inches. This damage site had not been significantly changed by re-entry aerodynamics/heating from the condition observed in the on-orbit video review. The missing window #8 perimeter tile V070-390068-059 piece, reported by the flight crew two days into the flight, most likely caused this damage (Figure 6). The edge of the tile fragment is believed to be the source of three small tears/scuff marks on the payload bay doors in a line between the original tile location and the damage site on the RH OMS pod. In addition, post flight analysis of samples from the OMS pod damage site revealed the presence of black RCG tile coating material. An improper repair to the carrier panel hole with subsequent contamination of the SIP/bondline is the leading candidate for the loss of the tile (IFA STS-68-V-01).

No TPS damage was attributed to material from the wheels, tires, or brakes. The tires were in excellent condition after a landing on the concrete runway.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned properly and the debris plungers were seated. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. No significant amounts of foam or red purge seal adhered to the LH2 ET/ORB umbilical near the 4-inch flapper valve. No debris was found on the runway beneath the ET/ORB umbilical cavities.

The number of tile damage sites on the base heat shield was less than usual with the majority of the hits occurring near the center of the heat shield. The Dome Mounted Heat Shield (DMHS) closeout blankets on all three SSME's were in excellent condition. Six TUFI tiles located on the triangular carrier panel between and below SSME #2 and #3 sustained no damage.

Orbiter windows #2, 3, 4, and #5 exhibited light hazing and streaks with windows #3 and #4 showing the most streaks. Numerous small impact sites occurred on window #2, 3, 4, and 5 perimeter tiles. Seven tile damage sites with two larger than 1-inch were present between and above windows #3 and 4. Tile hits in this area and window streaks have been attributed in the past to impacts from FRCS paper covers and/or cover RTV adhesive. Surface wipes were taken from all windows for laboratory analysis.

The drag chute appeared to have functioned nominally. All drag chute hardware was recovered and showed no signs of abnormal operation. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged.

Runway 22 had been swept/inspected by Air Force personnel prior to landing and all potentially damaging debris was removed. A post landing walkdown of Runway 22 was performed immediately after landing. No Shuttle flight hardware was found on the runway.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger was slightly less than average when compared to previous missions (Figures 7-8). The type of TPS damage is typical and not attributable to any single debris source.

Orbiter Post Launch Anomalies are listed in Section 10.

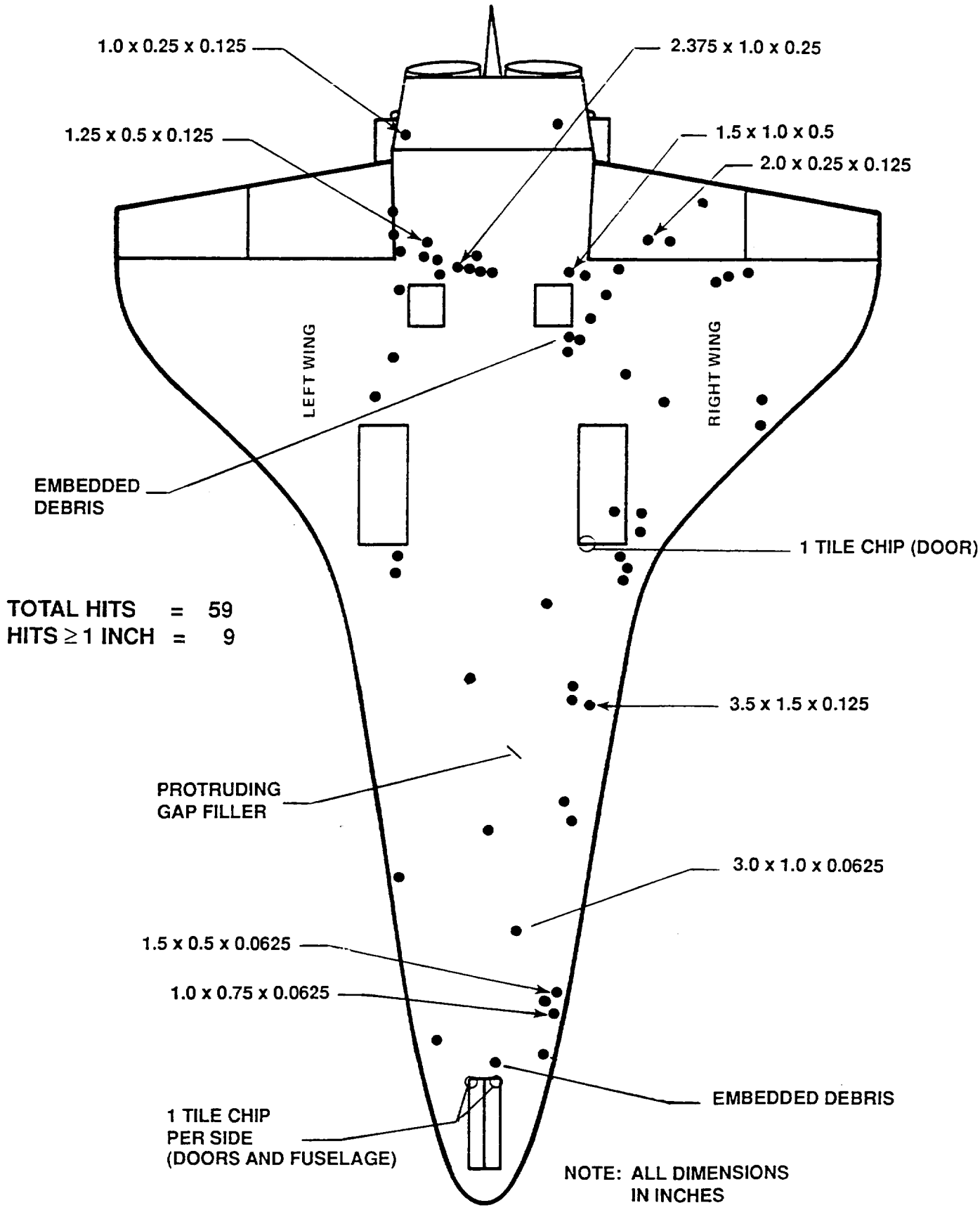


Figure 3 : Orbiter Lower Surface Debris Map

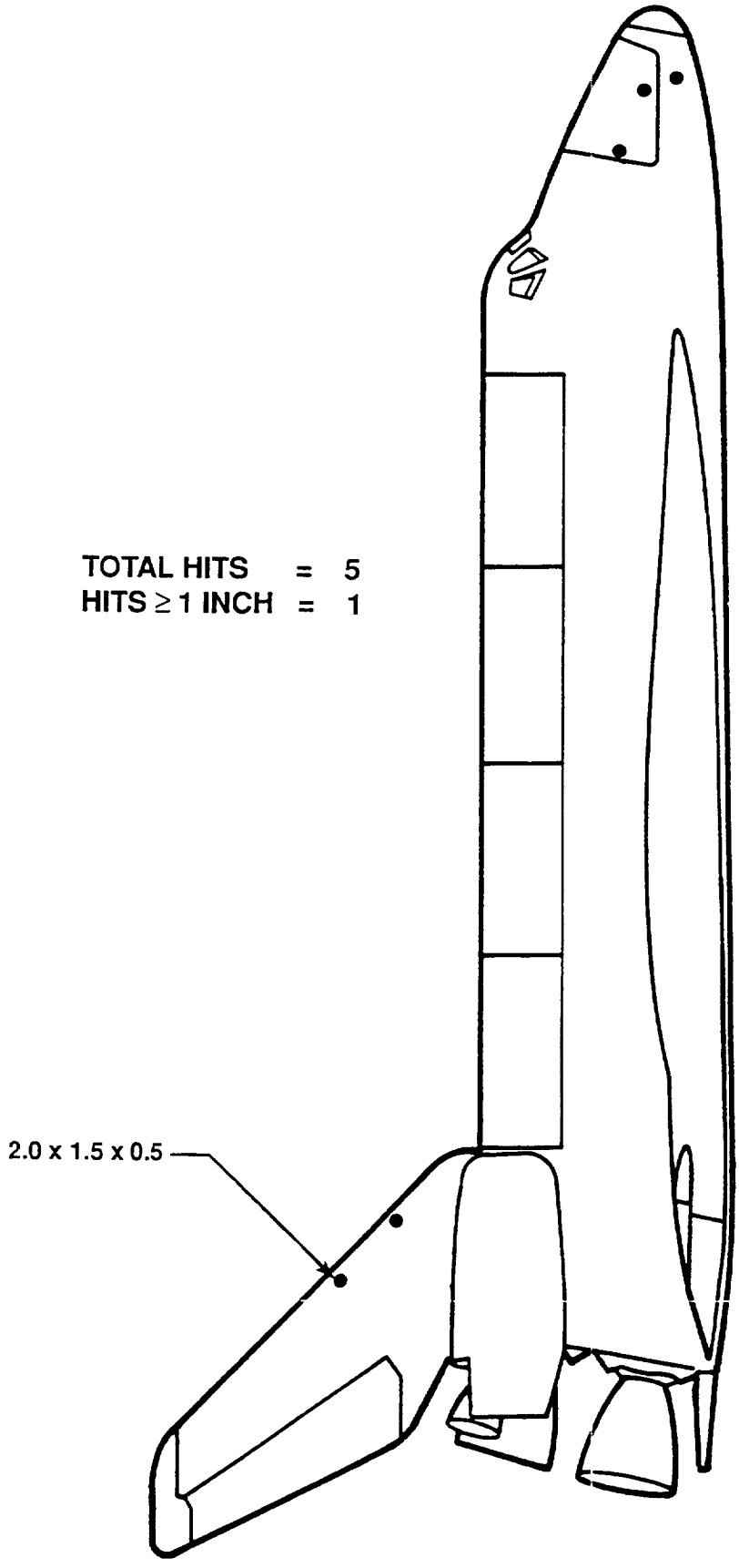
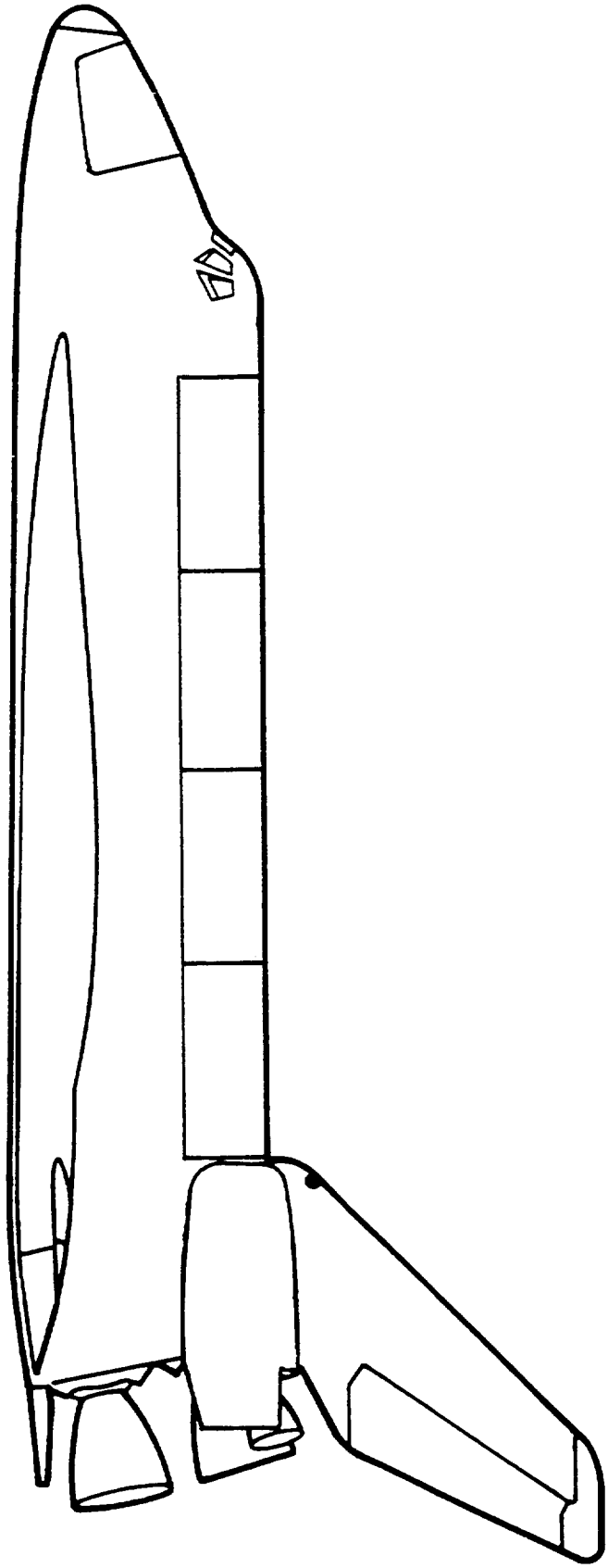


Figure 4 : Orbiter Right Side Debris Map

TOTAL HITS = 1
HITS ≥ 1 INCH = 0



NOTE: ALL DIMENSIONS
IN INCHES

Figure 5 : Orbiter Left Side Debris Map

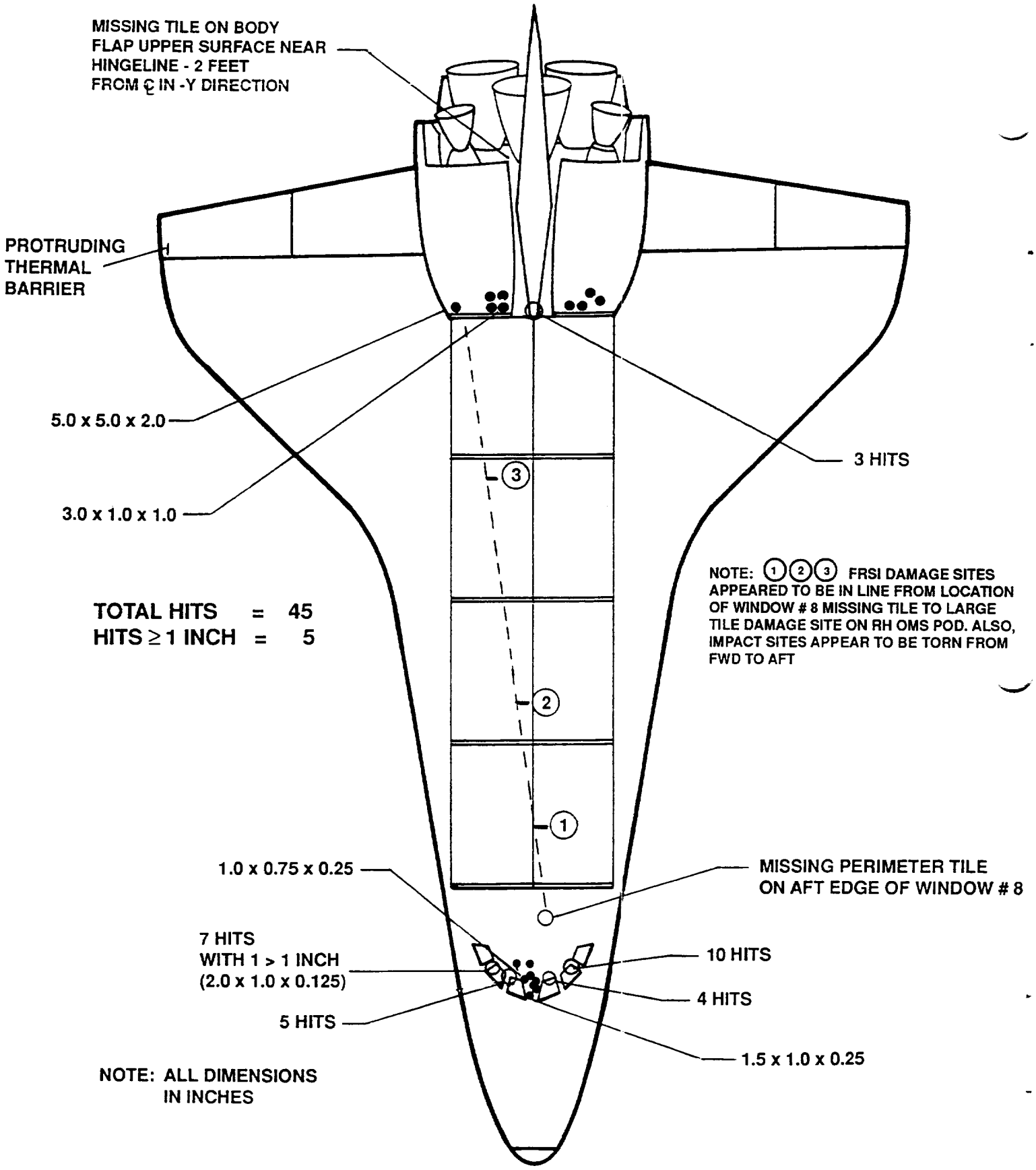


Figure 6 : Orbiter Upper Surface Debris Map

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
AVERAGE	14.1	90.7	21.3	131.6
SIGMA	7.2	43.8	10.1	56.5
STS-68	9	59	15	110

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYS
SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOUR

Figure 7 : Orbiter Post Flight Debris Damage Summary

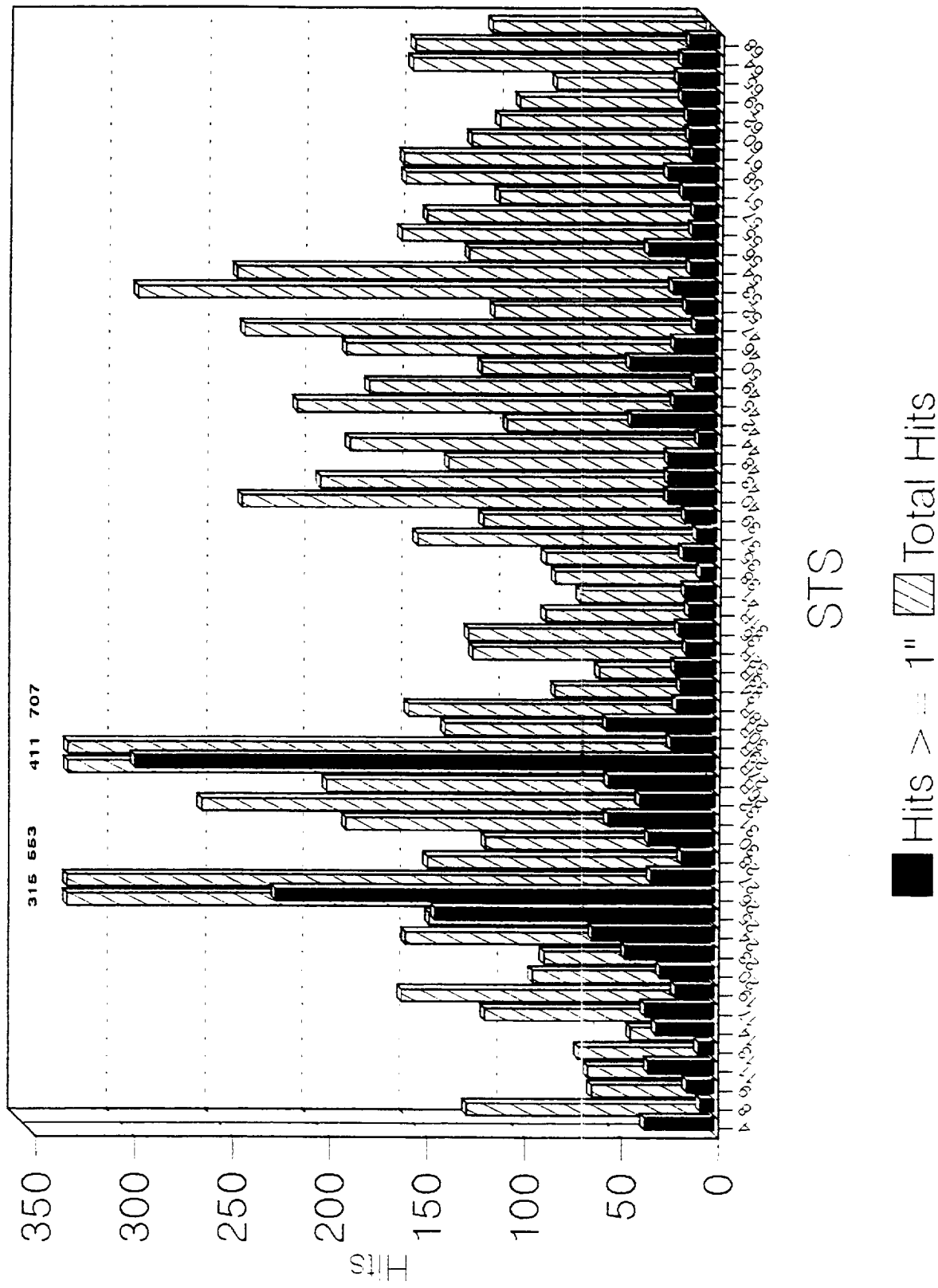


Figure 8 : Orbiter Debris Damage Comparison Chart

Photo 31 : Overall View of Orbiter Left Side

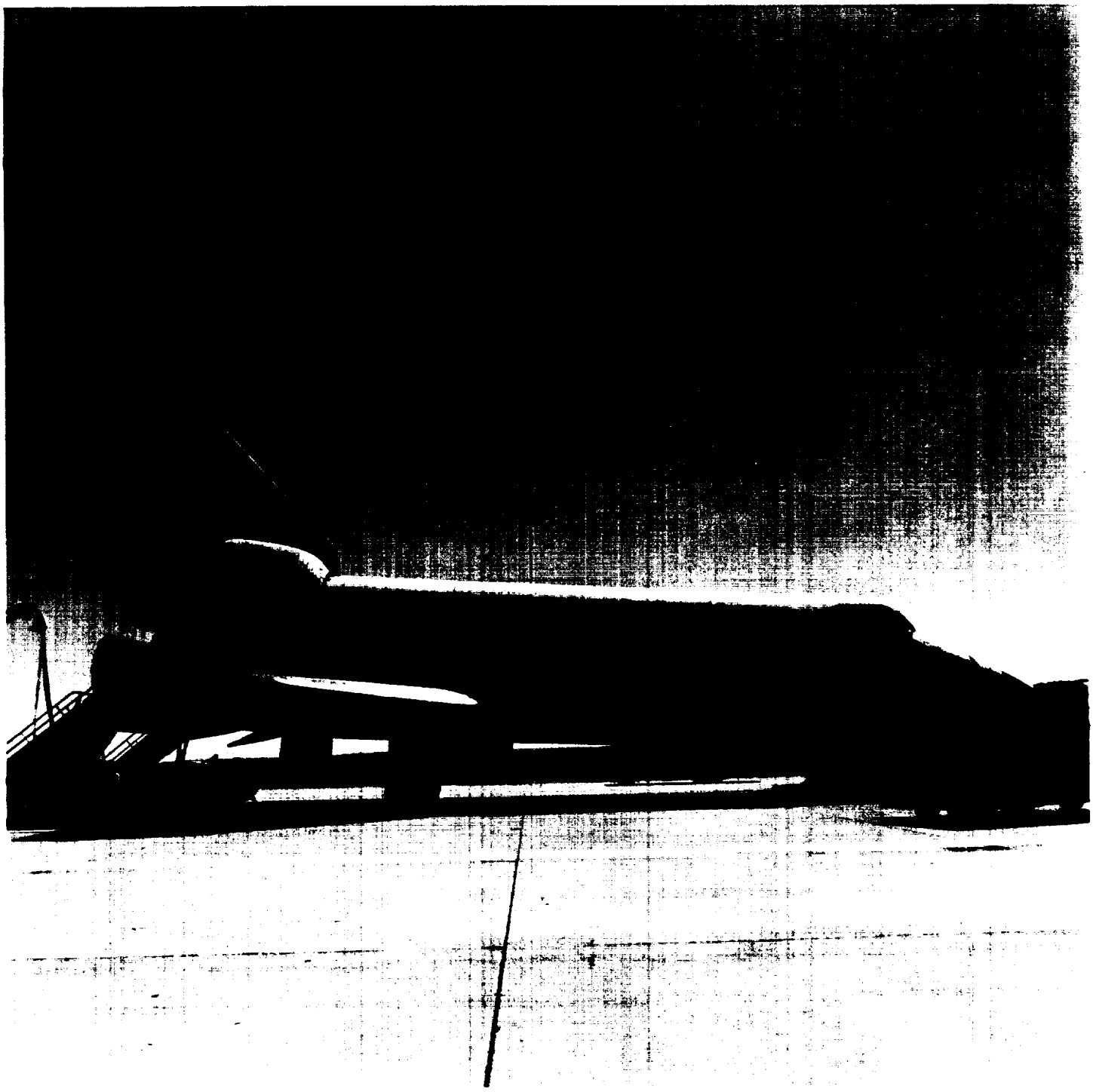


Photo 32 : Overall View of Orbiter Right Side

Photo 33 : Overall View of Orbiter Nose

Photo 34 : Ames Gap Filler Embedded in Tile

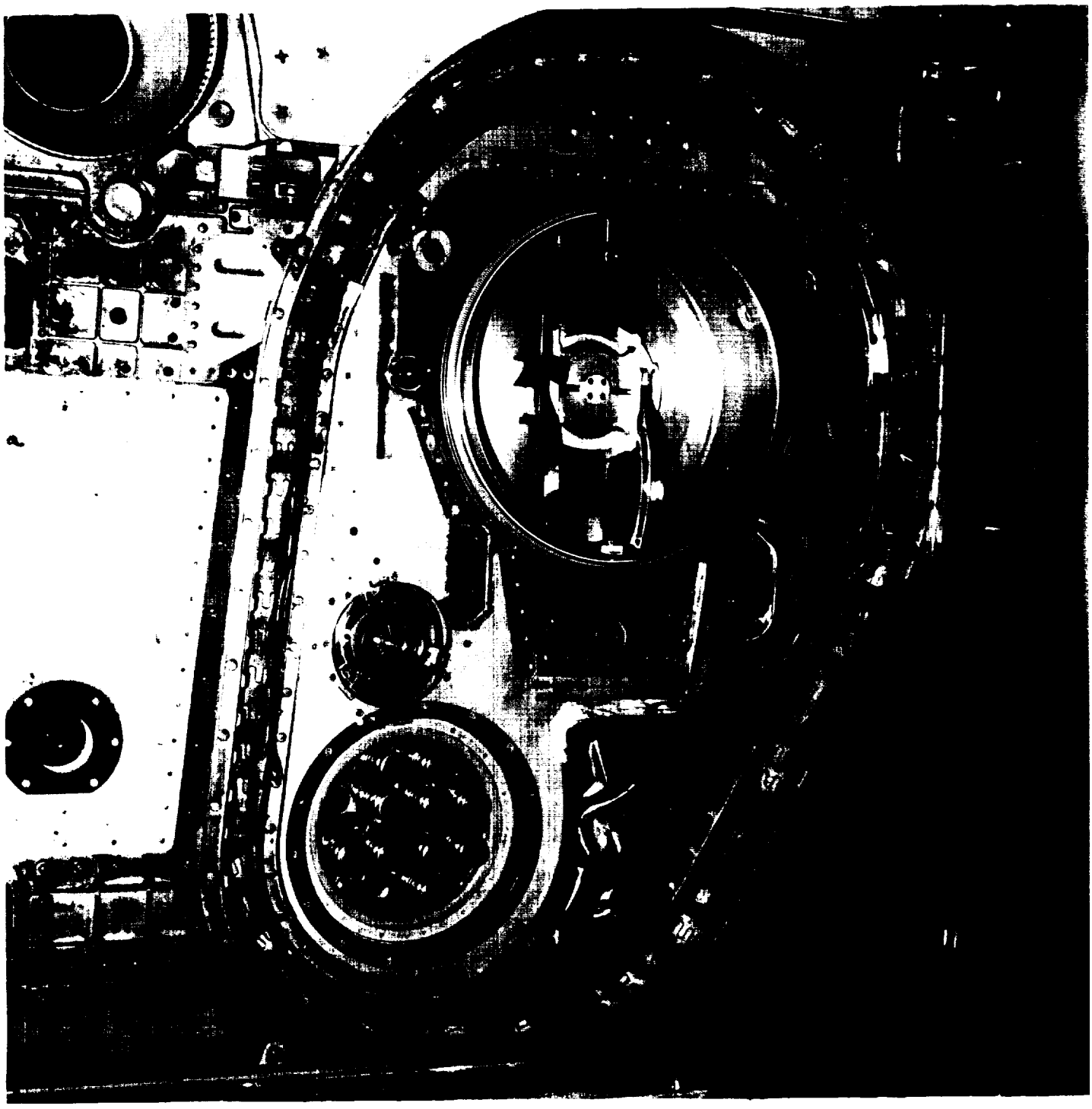


Photo 35 : LO2 ET/ORB Umbilical

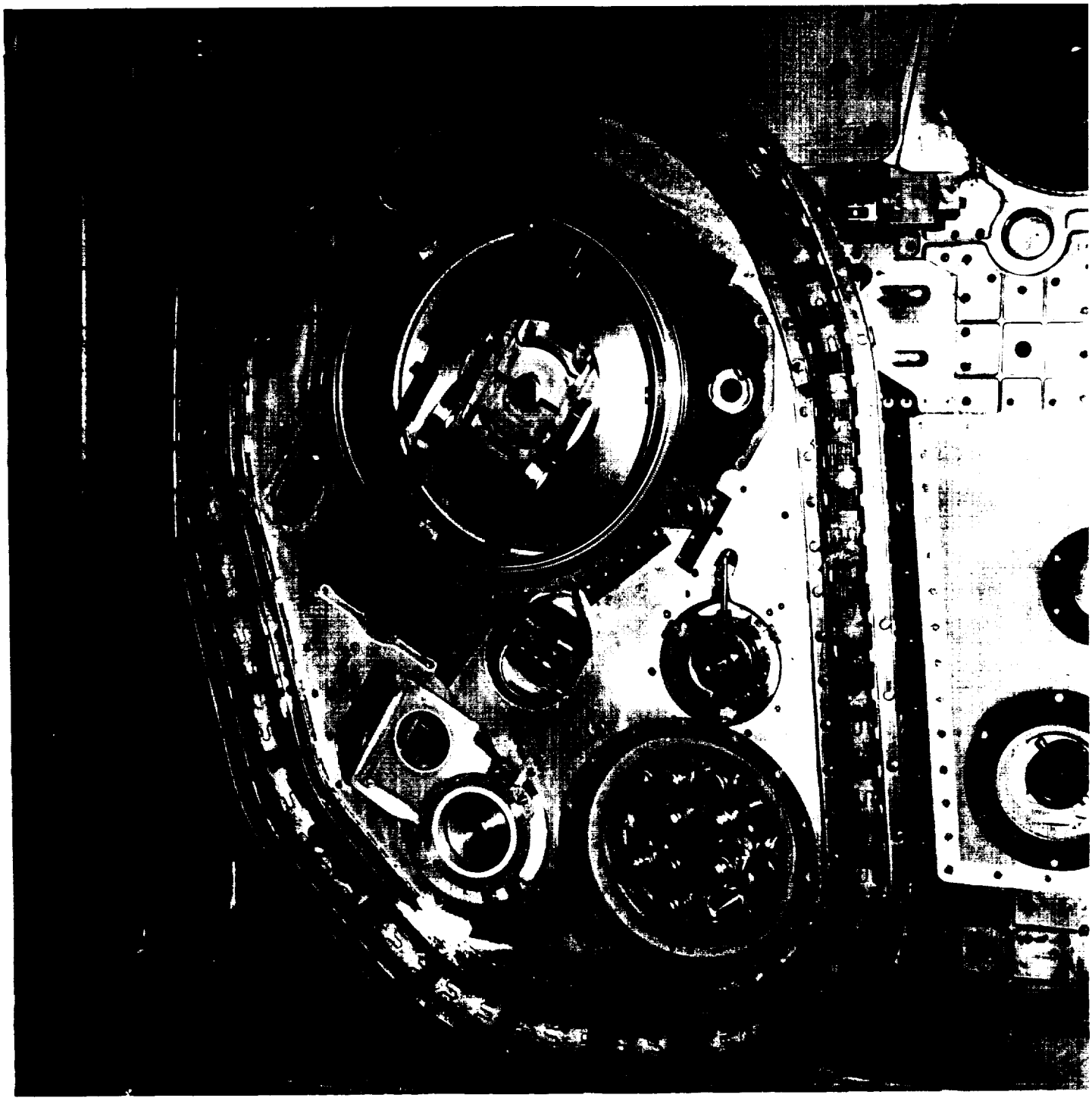


Photo 36 : LH2 ET/Orbiter Umbilical

Note closeout foam intrusion near LH2 recirculation line disconnect

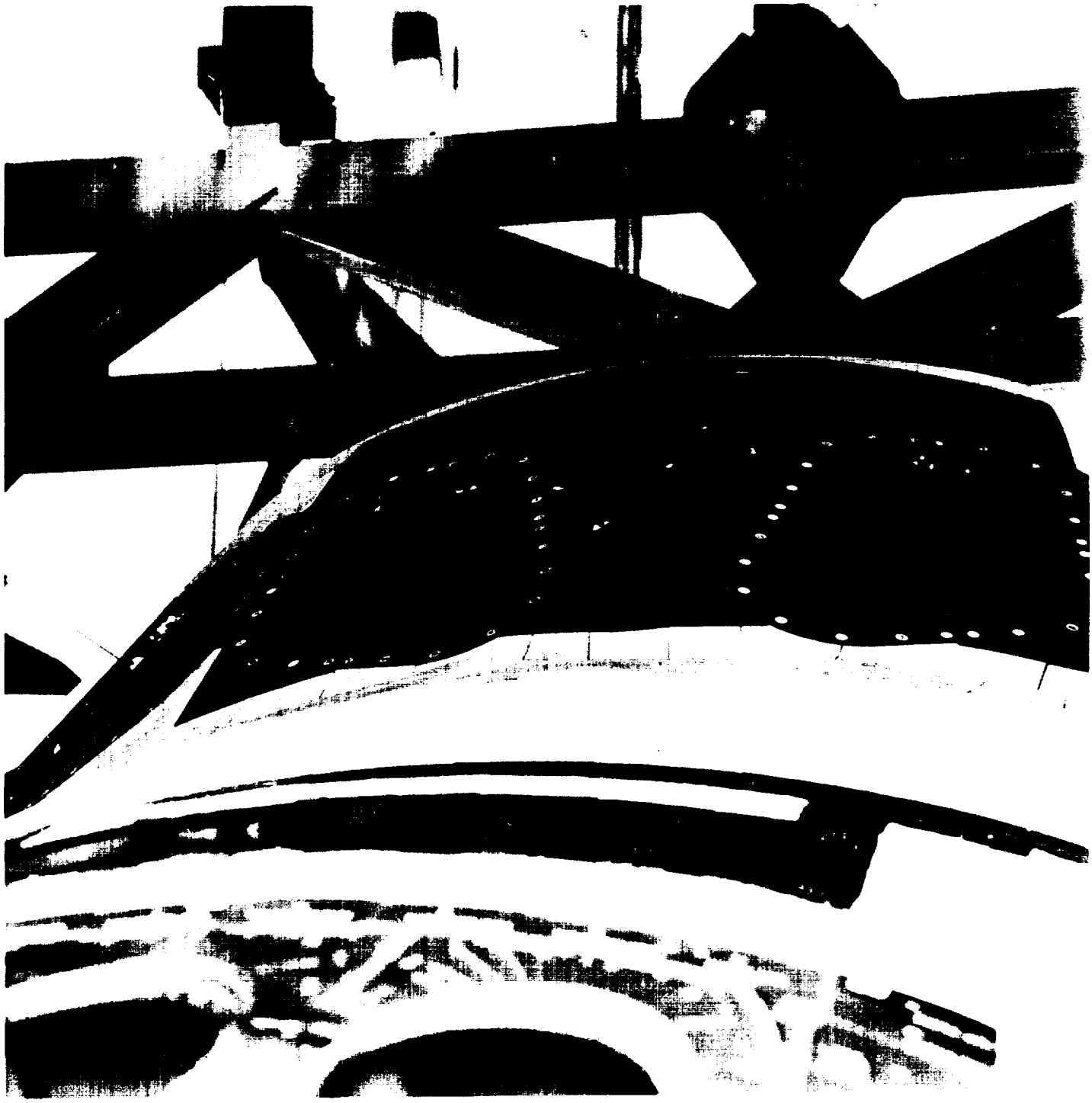


Photo 37 : Window Streaks and Perimeter Tile Damage

Orbiter windows #2, 3, 4, and #5 exhibited light hazing and streaks with windows #3 and #4 showing the most streaks. Numerous small impact sites occurred on window #2, 3, 4, and 5 perimeter tiles. Seven tile damage sites with two larger than 1-inch were present between and above windows #3 and 4. Tile hits in this area and window streaks have been attributed in the past to impacts from FRCS paper covers and/or cover RTV adhesive.

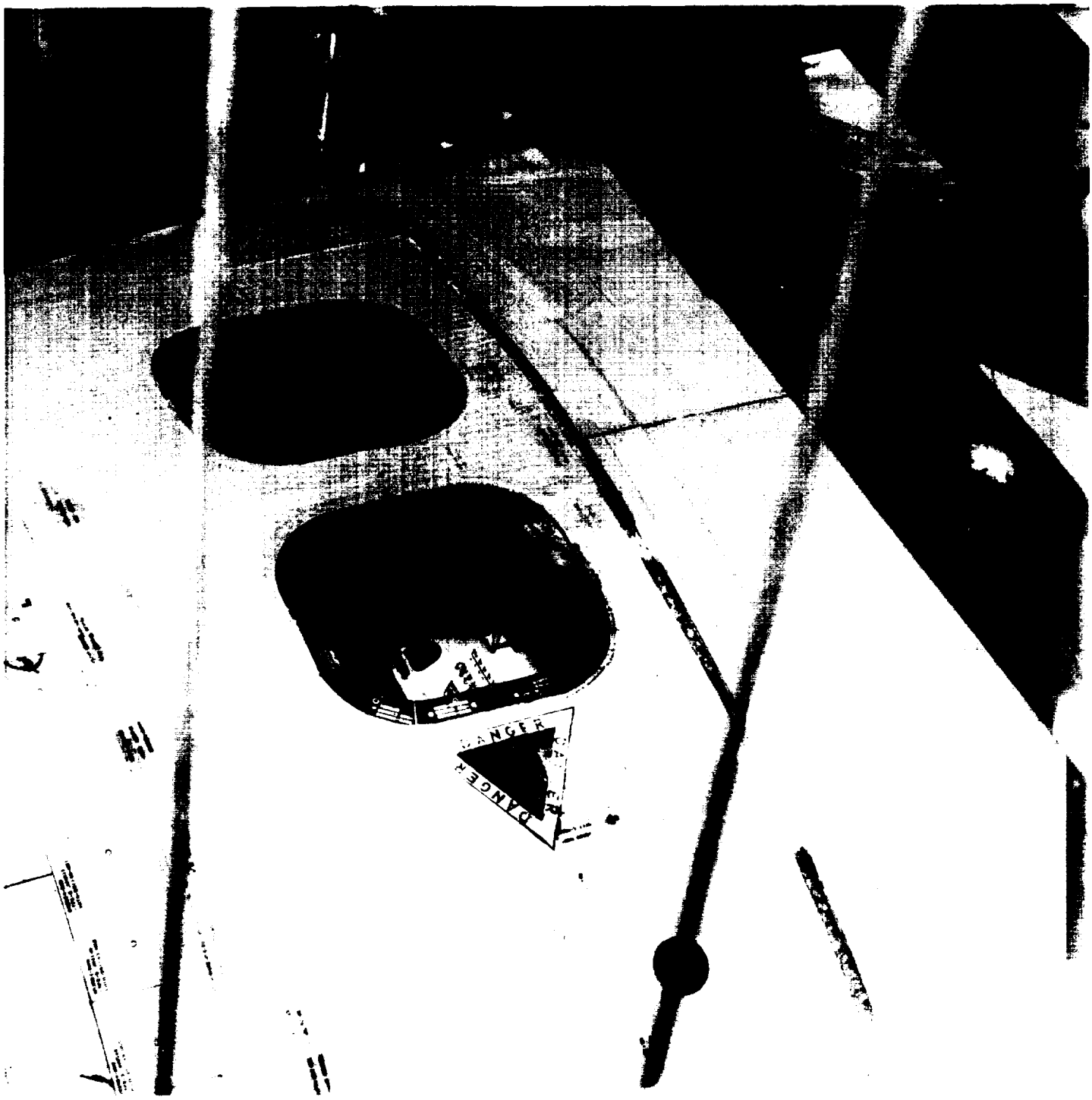


Photo 38 : Missing Perimeter Tile from Window #8

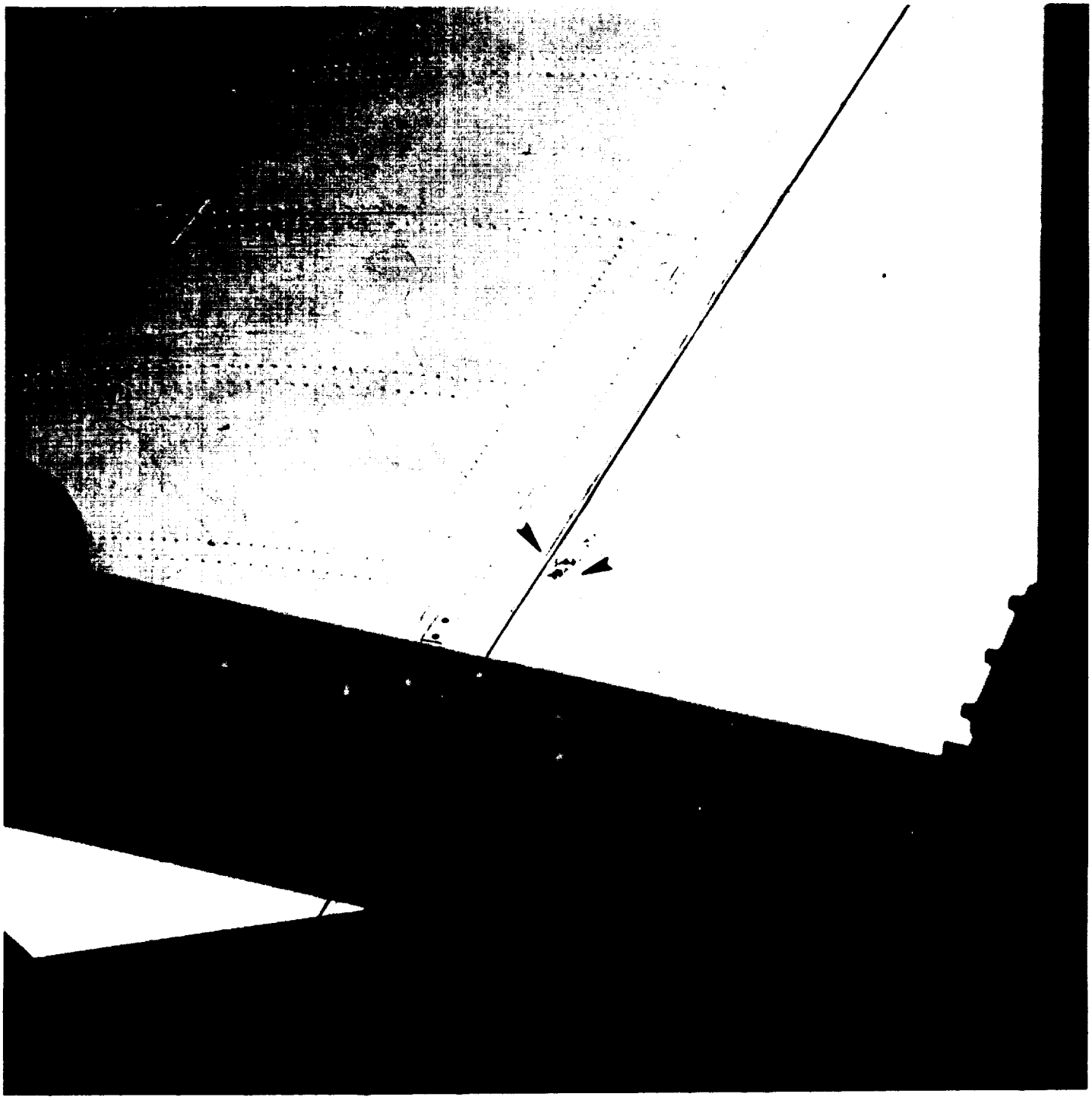


Photo 39 : Tear/Scuff Mark on Payload Bay Door FRSI

Photo 40 : Impact Damage Site on RH OMS Pod

9.0 DEBRIS SAMPLE LAB REPORTS

A total of ten samples were obtained from OV-105 Endeavour during the STS-68 post landing debris assessment at Dryden Flight Research Center. The submitted samples included: 8 wipes from Orbiter windows #1-8, 1 lower surface tile damage site debris, and 1 OMS pod tile damage site sample. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. An additional sample from the OMS pod tile damage site was submitted to the RI-DNY lab for analysis. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Black residue from the GOX vent seal and ET seal land area was sampled after the launch abort in August. Those results are included in this report. Debris sample results/analyses are listed by Orbiter location in the following summaries.

9.1 ORBITER WINDOWS

Samples from the windows indicated exposure to SRB BSM exhaust (metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (tile, tile repair, RTV and glass insulation), paints and primer from various sources. The variety of paint particulate colors (black, white, red, blue, green, and yellow) continues to be noted. Yellow paint particulate, observed in the previous mission STS-64 sampling, contained lead, which is typically used in facility/GSE paint. The window sample organic results are summarized in Figure 9. Specific identified materials included those associated with window covers (plastic polymers), RTV from RCS thruster nozzle cover adhesive and Orbiter TPS, and paint from various sources. There was no apparent vehicle damage related to these residuals.

9.2 LOWER SURFACE TILE

The lower surface tile damage site analysis provided evidence of fibrous tile material, tile coating material, and Hypalon paint particles. SRB Hypalon paint particles had been observed previously in the STS-65 lower surface tile samples. The paint particulate may not necessarily be the cause of the damage as tile damage sites have historically not retained the damage-causing debris.

9.3 RH OMS POD TILE

KSC lab results of the RH OMS pod tile damage site sample revealed fibrous tile, tile coating, and fused fibrous tile materials. The RI-DNY lab analysis was similar, but included a particle identified as black tile coating. The presence of the coating has been accepted as confirmation that the HRSI from the Orbiter left upper observation window #8 caused the OMS pod tile impact damage.

9.4 ET GOX VENT SEAL/FOOTPRINT (POST ABORT)

After the GOX vent hood retracted at T-3 minutes, black residue was observed on the -Y GOX vent seal footprint. The aborted launch attempt provided an opportunity to access the ET nose cone area and remove the GOX vent seal for chemical sampling. The results of the sampling are included in Figure 9. This unique sample data provided indication of assorted metallic particulates and inorganic contaminates. These data provide some enlightening as to the precise source of previously reported debris correlations.

9.5 NEW FINDINGS

This set of post flight debris residual samples did not yield any new findings. However, the post abort sample results from the GOX vent seal and ET footprint areas provided additional informative source data for a variety of metallic particulate. These new data will be inclusively resolved for the next debris mission publication.

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
68	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		ET GOX Vent Seal land area and GOX Seal Sample- Metallic Particulate
64	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer				
65	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		
59	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-Building insulation, wipe cloth Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV-RCS nozzle thruster cover Paint and primer				
62	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-Building insulation, wipe cloth Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV-RCS nozzle thruster cover Paint and primer				
60	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber - Building insulation, textile Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV-RCS nozzle thruster cover Paint and primer				

For data on previous missions refer to mission reports prior to STS-59

Figure 9 : Orbiter Post Landing Microchemical Sample Results

10.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, ten post launch anomalies, including one In-Flight Anomaly (IFA), were observed on the STS-68 mission.

10.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. MLP deck FIREX water spray nozzles caused TPS damage to the External Tank ET/ORB umbilicals during the abort. The nozzles are aligned per a facility drawing, which may need to be modified.

2. Dark residue from the GOX vent seals was present on the ET nosecone footprint area after the hood was retracted. Samples of the residue analyzed in the materials laboratory revealed pipe scale. This is a maintenance concern and a blow-down of the entire system should correct the problem.

3. The LH2 TSM door did not close until T+7 seconds MET. This condition allowed exhaust plume impingement inside the TSM.

4. A cable tray cover was found on the pad apron west of the FSS after launch.

10.2 EXTERNAL TANK

1. Foam, approximately 10 inches in length, was missing from an intertank stringer head at XT-1050 forward of the bipods and to the -Y side of centerline. The divot exposed the substrate.

2. A divot, approximately 5 inches in diameter but shallow in depth, occurred in the LH2 tank acreage aft of the LH2 tank-to-intertank flange closeout between the -Y thrust panel and the -Y bipod spindle housing closeout.

3. Two divots, 10 to 12 inches in diameter, were present in the intertank acreage/stringers adjacent to and into the LH2 tank-to-intertank flange closeout on the -Z side of the tank between the RSS antenna and -Z intertank vent. A third divot, approximately 8 to 10 inches in diameter, occurred in the LH2 tank-to-intertank flange closeout aft of the flight umbilical carrier plate area. A fourth divot approximately 6 inches in diameter was visible in the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant on the +Y side of the LO2 feedline.

10.3 SOLID ROCKET BOOSTERS

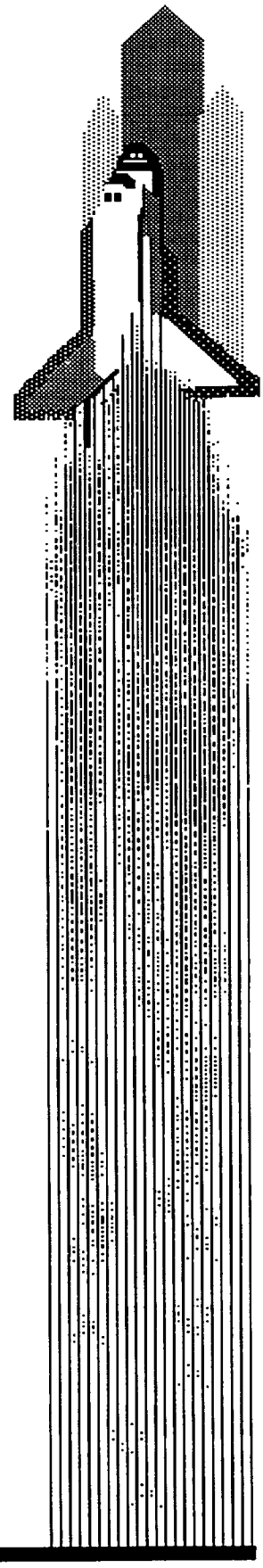
1. Both right and left frustums had a combined total of 41 MSA-2 debonds.

10.4 ORBITER

1. A tile gap filler protruded from the left inboard lower surface near the hinge during SSME ignition.

2. An improper repair to the window perimeter tile carrier panel hole with subsequent contamination of the SIP/bondline is the leading candidate for the loss of the tile fragment from window #8 (IFA STS-68-V-01). The tile fragment fell aft during ascent causing small tears on the payload bay doors and a deep impact site on the RH OMS pod.

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY



Space Shuttle

Photographic and Television Analysis Project

STS-68 Summary of Significant Events

December 8, 1994

Space Shuttle Photographic and Television Analysis Project

STS-68 Summary of Significant Events

Project Work Order - SN-52V

Approved By

Lockheed

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Table of Contents

List of Figures and Tables

1. OV-105 STS-68 FILM/VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

Endeavour (OV-105) launched on mission STS-68 from Pad A at 11:16:00.018 Coordinated Universal Time (UTC) on September 30, 1994 (day 273) as seen on camera E-9. Solid rocket booster (SRB) separation occurred at 11:18:03.608 UTC as seen on camera E-207.

On launch day, 22 videos were screened. Following launch day, 53 films were reviewed. Camera E-62 did not run properly and was excluded from the received launch films.

No anomalies were observed during launch.

Several tracker camera films were re-screened in an effort to find events related to damage seen on-orbit by the crew on the right OMS pod and debris smears on the Orbiter windows. This re-screening was done at the request of the Mission Evaluation Room Manager. While several pieces of debris were seen forward of the vertical stabilizer and near the right OMS pod at different times during ascent, no definitive source for the right OMS pod damage was found. However, the debris and two white streaks seen at approximately 36 seconds MET are considered to be possibly related to the right OMS pod damage. Sections 2.1.1.4 and 2.3.1 respectively provide more information on debris and vapors streaks observed during ascent. No debris was seen in the vicinity of the Orbiter windows.

Thirty-eight images of the STS-68 external tank were acquired after separation with a Nikon camera using a 300 mm lens and a 2X extender (DTO-312, Method 3). Divots seen on the external tank are described in section 2.4 of this report.

1.1.2 On-Orbit

No on-orbit events required PTAP support.

1.1.3 Landing

Two opportunities for landing of STS-68 on October 11, 1994 at the Kennedy Space Center (KSC) were waived due to weather constraints.

Endeavour landed on runway 22 at Edwards Airforce Base on October 11, 1994 (day 284). Six videos of the Orbiter's approach and landing were received. No anomalies were detected during the screening of the replays. Left main gear touchdown was at 17:02:07.889 UTC, right main gear touchdown occurred at 17:02:08.990 UTC and nose wheel touchdown was at 17:02:20.936 UTC as seen on camera DTV-1. Wheel stop was noted at 17:03:08.817 UTC on camera DTV-1.

No major anomalies were noted in any of the approach, landing and rollout video views screened.

The deployment of the drag chute appeared as expected. Event times were obtained from camera DTV-1 and are shown below:

Event Description	Timing UTC
Drag chute initiation	17:02:10.573 UTC
Pilot chute inflation	17:02:11.426 UTC
Bag release	17:02:12.027 UTC
Drag chute inflation in reefed configuration	17:02:13.028 UTC
Drag chute inflation in disreefed configuration	17:02:16.198 UTC
Drag chute release	17:02:45.260 UTC

Table 1.1.1 Landing Event Times.

The following items were noted during the post landing walk around: clear fluid (possibly water) dripping from the TPS tiles near the LH2 umbilical area and off the LH2 umbilical door, a small discoloration noted on the LH2 umbilical well 4-inch disconnect, slight TPS damage on the base heat shield between the SSMEs and on the top surface of the body flap, TPS damage to the right OMS pod stinger, and slight tile damage near the nose gear door. The drag chute housing and the tires appeared to be in satisfactory condition.

1.2 TIMING ACTIVITIES

All videos except ET-208 had timing and film cameras E-1, E-2, E-3, E-4, E-5, E-6, E-7, E-8, E-9, E-10, E-11, E-12, E-13, E-14, E-15, E-16, E-17, E-18, E-19, E-20, E-25, E-26, E-52, E-54, E-57, E-59, E-222 and E-224 had in-frame alphanumeric timing. These videos and films were used to time specific mission events during the initial screening. The following events were timed on four film cameras:

Camera	Frame	Comments	Timing (UTC)
E-207:	2425	Beginning of body flap motion	273:11:16:40.741
	2625	End of body flap motion	273:11:16:48.011
	6403	White flash along right pod	273:11:17:45.709
	5700	Start of recirculation	273:11:17:34.238
	6430	End of recirculation	273:11:17:46.149
	7508	SRB separation	273:11:18:03.608

Table 1.2.1 Film Camera Timing Determinations.

Camera	Frame	Comments	Timing (UTC)
E-208	4091	Piece of debris fell from SRB plume prior to SRB separation	273:11:17:59.009
	4114	Piece of debris fell from SRB plume prior to SRB separation	273:11:17:59.511
	4430	SRB separation	273:11:18:03.724
E-220	4722	Debris	273:11:16:45.838
	4751	Debris	273:11:16:46.152
E-223	4591	Single light colored piece of debris, first seen forward of vertical stabilizer	273:11:16:43.715
	4598	Same piece of debris last seen aft of vertical stabilizer	273:11:16:43.957
	5195	Flare noted in SSME plume	273:11:16:50.230
	5603	Flare noted in SSME plume	273:11:16:54.636

Table 1.2.2 Film Camera Timing Determinations (continued).

2. SUMMARY OF SIGNIFICANT EVENTS ANALYSIS

2.1 DEBRIS

2.1.1 Debris near the Time of SSME Ignition

2.1.1.1 LH2 and LO2 Tail Service Mast (TSM) T- 0 Umbilical Disconnect Debris

(Cameras E-5, E-17, E-18, E-19, E-20, E-25, E-76, E-77, OTV-049, OTV-050, OTV-O70)

Normal ice debris was noted falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at SSME ignition through liftoff. None of the debris was observed to strike the vehicle. No follow-up action was requested

2.1.1.2 LH2 and LO2 ET/Orbiter Umbilical Disconnect Debris

(Cameras E-5, E-6, E-25, E-26, E-31, E-36, E-40, E-57, E-60, OTV-009, OTV-054, OTV-063)

Normal ice debris was noted falling from the LH2 and LO2 ET/Orbiter umbilical disconnect areas at SSME ignition through liftoff. Multiple pieces of light colored debris (probably ice) were seen striking the umbilical sill and the electric cable tray during SSME startup (as seen on OTV-009, OTV-063). No damage to the launch vehicle was apparent in either case.

2.1.1.3 Debris Near the Time of SRB Ignition

(Cameras E-4, E-5, E-8, E-9, E-10, E-11, E-14, E-16, E-25)

As on previous missions, several pieces of debris were noted originating from the SRB flame duct area after SRB ignition. A single piece of red colored debris (probably flame duct material) struck the right SRB holddown post M-2 after liftoff. A second piece of debris (probably SOFI) struck the left SRB. No damage was observed in either case.

2.1.1.4 Debris after Liftoff

(Cameras E-34, E-40, E-52, E-54, E-57, E-59, E-60, E-63, E-76, E-205, E-207, E-208, E-212, E-213, E-218, E-220, E-222, E-223, E-224, ET-208, OTV-054, OTV-070, OTV-071, KTV-4A, KTV-13)

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) at liftoff, throughout the roll maneuver, and beyond on the launch tracking views. Most of the debris sightings were probably reaction control system (RCS) paper or ice from the ET/Orbiter umbilicals. None of the debris was observed to strike the vehicle.

2.1.1.5 Debris seen Between 26 and 72 Seconds MET

26 seconds - A single piece of light colored debris, first observed at the edge of the SRB plume, broke into several small pieces as it traveled aft of the vehicle. (Cameras E-52, E-57, E-224)

36 seconds - A small piece of light colored debris was first observed near the leading edge of the right OMS pod at 11:16:36.183 UTC. The debris traveled aft of the vehicle and was in view for 0.073 seconds. (Camera E-224)

38 seconds - A small light colored piece of debris seen falling aft of the body flap appeared to strike the left SRB aft skirt. No damage to the vehicle was detected. (Camera E-207)

43 seconds - A single light colored piece of debris, first seen forward of the vertical stabilizer, fell aft into the SRB plume. The debris appear to vaporize as it passed aft of the vertical stabilizer. At approximately this time several pieces of debris were observed falling aft of the base of the vertical stabilizer on cameras E-222 and E-224. (Cameras E-205, E-223, E-222, E-224)

65 - 72 seconds - Multiple pieces of light colored debris were noted falling aft of the SLV along the SRB plume. (Cameras E-220, KTV-4A)

2.2 MLP EVENTS

2.2.1 SRB Shoe Rotation
(Cameras E-8, E-13)

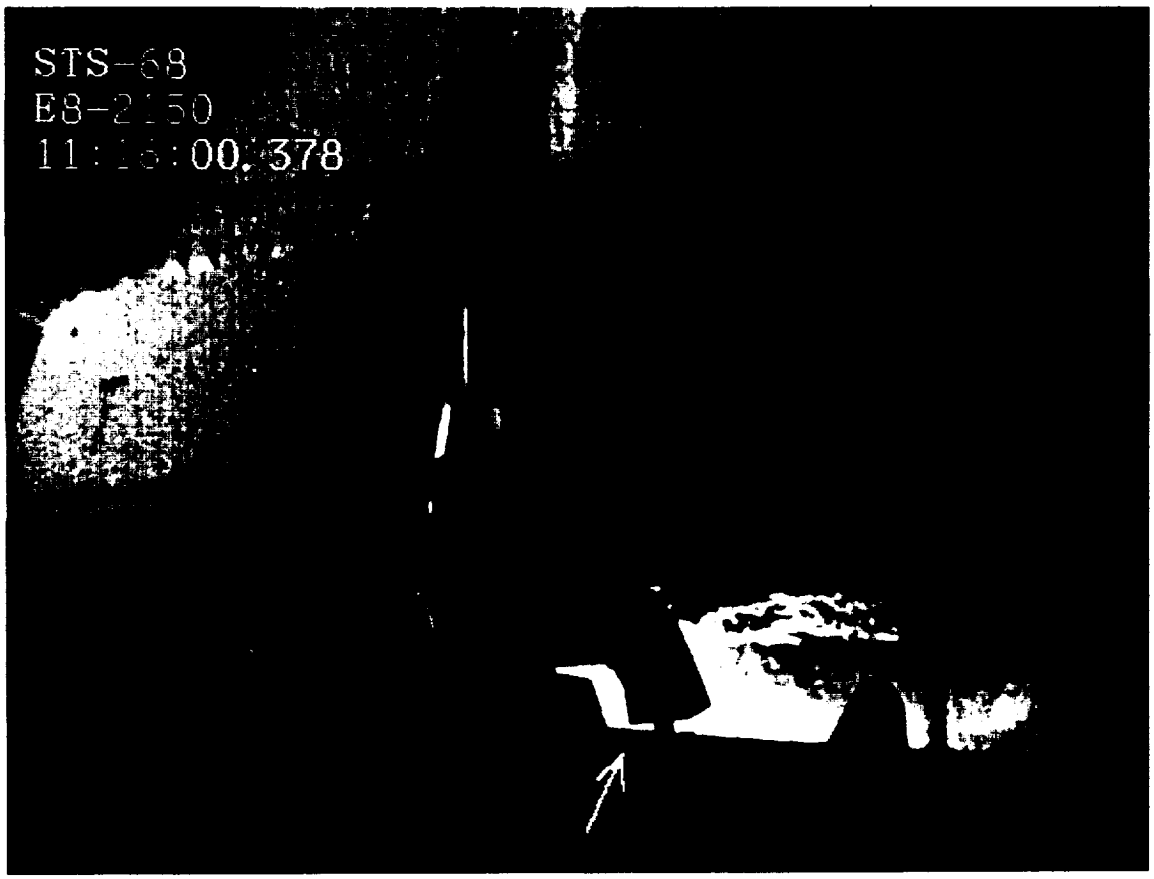


Figure 2.2.1 Right SRB Shoe Rotation at Holddown Post M-2 *(Camera E-8).*

SRB shoe rotation was observed on two SRB holddown posts: RSRB holddown post M-2 and LSRB holddown post M-6. No follow-up action was requested.

2.2.2 Orange Vapor (Possibly Free-burning Hydrogen)
(Cameras OTV-063, OTV-070, OTV-071, E-16, E-18, E-20)

Orange vapor (probably free-burning hydrogen) was seen between the body flap and the SRBs at T-5.673 seconds MET. Orange and green vapors were seen above the rims of the SSMEs, near the vertical stabilizer, surrounding the left OMS nozzle, and forward of the aft edge of the left OMS pod at T-5.305 seconds MET. This event has been noted on past missions and would become a concern if the vapor was seen as high as the umbilical areas. On this mission, however, the vapor was below the umbilicals and no follow-up action was requested.

2.2.3 LH2 Tail Service Mast (TSM) T-0 Housing Door Closing
(Cameras E-2, E-25, E-76)

The LH2 TSM T-0 housing door did not close after umbilical retraction at liftoff. No follow-up action was requested.

2.3 ASCENT EVENTS

2.3.1 White Vapor Streaks
(Cameras E-223, E-224, E-205, E-207, E-222, KTV-4A)

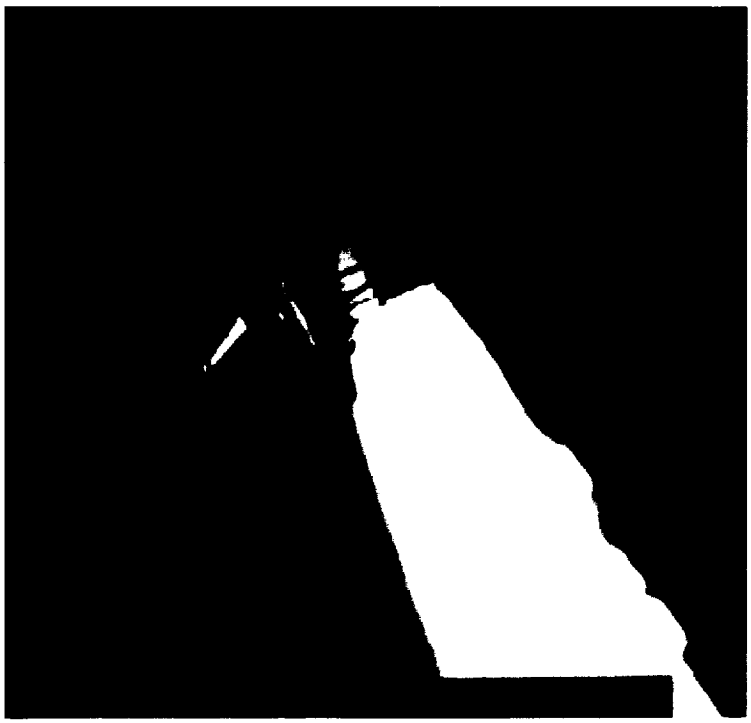


Figure 2.3.1 White Vapor Seen Aft of the Right OMS Pod *(Camera KTV-4A).*

Two white vapor streaks were seen originating from the forward edge of the right OMS pod at 36.2 seconds MET (Figure 2.3.1). On camera E-224, a small light colored piece of debris was observed near the leading edge of the right OMS pod 0.041 seconds prior to the appearance of the white vapor streaks.

2.3.2 Body Flap Motion (Task #4)
(Camera E-207)

Body flap motion was seen on this mission. This event has been tracked on all missions since reflight. Currently, motion data is being reviewed. If measurable motion is determined, deflection measurements shall be reported.

2.3.3 Linear Optical Effect
(Cameras E-207, E-208, KTV-13, ET-208)

Linear optical effects were seen between 69 and 90 seconds MET. Engineers at JSC have previously attributed this event seen on earlier missions, to the manifestation of shock waves around the shuttle launch vehicle. No follow-up action was requested.

2.3.4 Recirculation
(Cameras E-205, E-207)

The recirculation or expansion of burning gases at the aft end of the Shuttle Launch Vehicle prior to SRB separation has been seen on nearly all previous missions. Recirculation on STS-68 was observed between approximately 94 and 106 seconds MET on camera E-207.

2.4 ONBOARD PHOTOGRAPHY OF THE ET (DTO 312)

2.4.1 Analysis of Handheld Photography of the ET from DTO-312 (Task #6)

DTO-312 handheld photography of the STS-68 external tank (after separation) was acquired using a Nikon camera with a 300 mm lens and a 2X extender (Method 3). Thirty eight exposures from Magazine 01 were acquired. The exposure and focus is good on all frames. Timing data is present on the film. The first picture was taken at 11:29:41 UTC (approximately 13.7 minutes after liftoff) and the last picture was taken at 11:34:50 UTC.

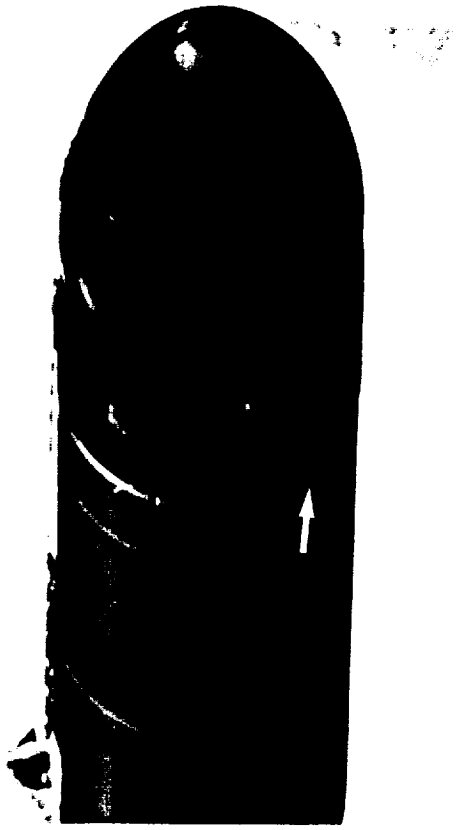


Figure 2.4.1 White Mark Visible on the ET LH2 Tank/Intertank Interface (STS068-01-011)

All sides of the external tank (ET) were imaged. The external tank appeared in good condition. No unusual markings seen on the ET that were obvious candidates for the source of damage to the Orbiter right OMS pod. Four white marks (probable divots) were visible on the external tank TPS: (1) A white mark was visible on the side of the external tank away from the Orbiter (+Y/-Z axis) at the LH2 tank/intertank interface (Figure 2.4.1). This divot was approximately 13 by 11 inches in size. (2) A white mark was visible on the LH2 tank TPS aft of the GUCP (-Y axis). (3) A white mark was visible on the LH2 tank TPS just aft of the LH2 tank/intertank interface and in the -Y direction from the forward ET/Orbiter attach bipod. (4) A white mark was visible on the aft third of the hydrogen tank on the -Y axis.

Video of the external tank after separation from the Orbiter was taken by the astronauts. Venting and white debris (probably ice) coming from the ET Orbiter umbilical area were visible. These events are considered normal and no further analysis has been requested.

2.4.2 Umbilical Well Camera Analysis (Task #5)

Three rolls of STS-68 umbilical well camera film were received at JSC: the 35 mm film from the LO2 umbilical and two 16 mm films (5 mm lens and 10 mm lens) from the LH2 umbilical.

The +X translation maneuver was not performed on STS-68. Although all umbilical well cameras performed nominally, the ET nose tip was not imaged on the 35mm umbilical well film.

The following items seen on the umbilical well films are not considered anomalous but do merit mentioning:

2.4.2.1 35 mm Umbilical Well Film Screening

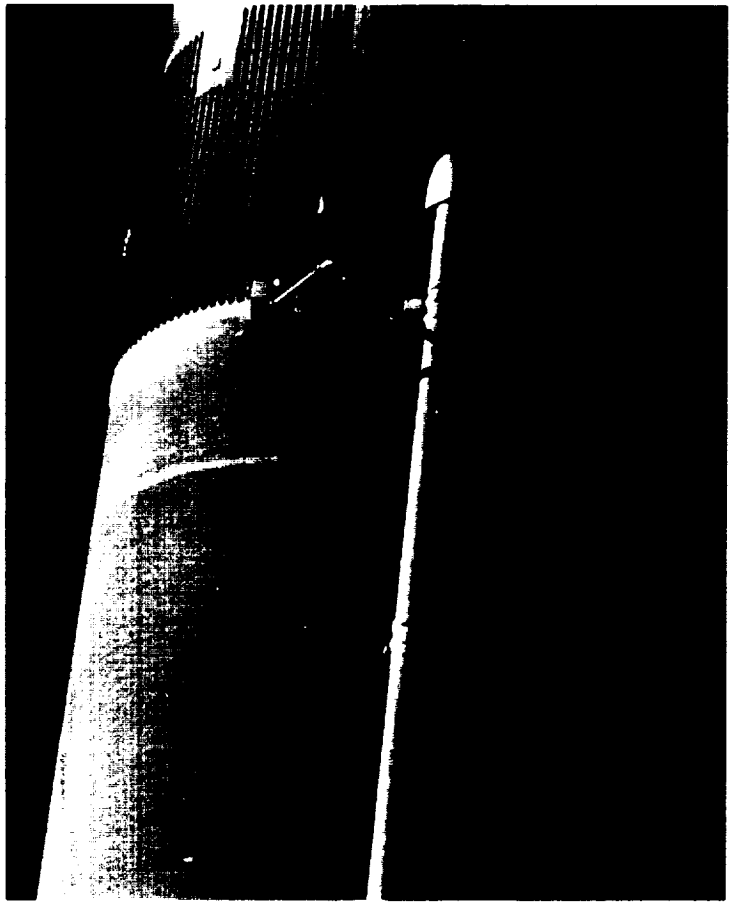


Figure 2.4.2.1 Light Colored Mark on Intertank Stringer Head *(STS068-300-060).*

1) A light colored mark, probably missing TPS, is visible on an intertank stringer head forward of the ET/Orbiter forward attach bipod. There is a dark area in the center of the light colored mark(Figure 2.4.2.1). This mark measured 12 by 5 inches in dimensions.

2) A light colored mark is visible on the aft edge of the cross beam just forward of the LO2 umbilical.

3) Minor TPS erosion and voids are visible on the aft LO2 feed line bellows and support bracket.

4) Minor erosion or chipping on the LH2 tank TPS is visible in the -Y direction from the LO2 feedline.

5) The small white erosion or "pop corn" marks visible on the intertank in the vicinity of the forward ET/Orbiter attach bipod are less than seen on most previous missions.

6) Multiple TPS erosion marks and voids are visible on the LH2 tank TPS in the -Y direction from the aft LO2 feed line support bracket just forward of the cross beam.

7) Small white debris objects are visible throughout the film sequence. Many of these white debris objects appear to be frozen hydrogen.

Note: The LO2 umbilical is in shadow and is difficult to see. The presence of the LO2 lightning contact strips was not verified. The presence of the red seal around the EO-3 fitting was not confirmed.

2.4.2.2 16 mm Umbilical Well Film Screening (5 mm & 10 mm Lens)

1) Numerous light colored pieces of debris (probably insulation) are in view throughout the SRB film sequence. Typical chipping and erosion of the electric cable tray are visible. Erosion and scarring of the ET/LSRB aft attach are visible. A blistering of the fire barrier coating on the outboard side of the LH2 umbilical is apparent.

2) A string like flexible piece of debris first seen near the vertical component of the electric cable tray and then moving in front of the left SRB is visible on the 10 mm lens view prior to SRB separation (frames 334 through 410).

3) A dark, rectangular shaped piece of debris can be seen coming from behind the electric cable tray on the 5 mm lens view prior to SRB separation (frame 934).

4) A partially detached piece of TPS is visible at the base of the ET/LSRB attach after SRB separation. Debris is visible falling from the ET/LSRB attach area after SRB separation.

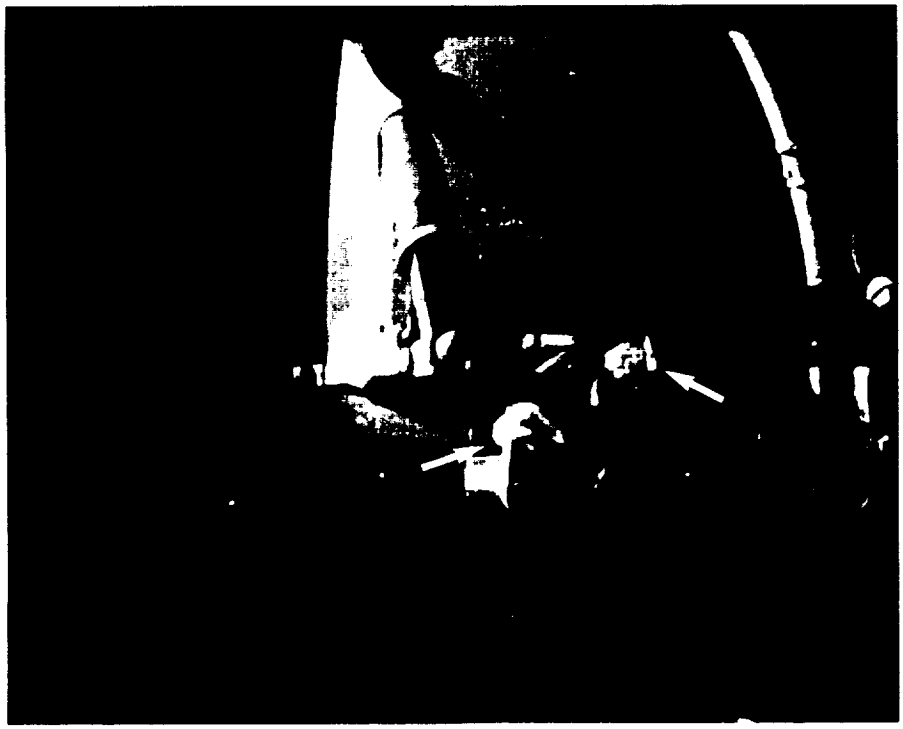


Figure 2.4.2.2 Frozen Hydrogen at LH2 Umbilical *(5mm Lens, Frame 6095).*

5) A large piece of frozen hydrogen is visible in the orifice of the LH2 umbilical 17 inch line connect after ET separation. A white mark near the cross beam is visible forward and to the right of the LH2 umbilical (5 mm lens frame 6095). KSC reported that the white area was ice on a fitting which is not insulated. The red seal near the EO-2 fitting appeared in place.

6) A small light colored piece of debris can be seen striking the base of the horizontal section of the electric cable tray on the 5 mm lens view after ET separation (frame 2677). White debris (frozen hydrogen) is also visible striking the electric cable tray on frame 3476. No damage to the ET is visible.

7) A flat, thin piece of debris is visible tumbling aft along the -Y thrust strut after ET separation on the 10 mm lens view (frame 6740).

8) A bright appearing piece of debris is visible on the +Y side of the ET after ET separation on the 10 mm lens view (frame 8402).

2.5 ON-ORBIT EVENTS

There were no on-orbit events which required PTAP support.

2.6 LANDING EVENTS

2.6.1 Landing Sink Rate Analysis (Task #3)

The sink rate of the Orbiter was determined over a one-second interval prior to main gear and nose gear touchdown. The calculation method described in section 2.6.1.1 was used for all nose and main gear sink rate determinations.

2.6.1.1 Landing Sink Rate Analysis Using Film
(Cameras E-1008, E-1036)

Camera E-1036 was used to determine the landing sink rate of the main gear. The analysis considered approximately one second of imagery immediately prior to touchdown. Data was gathered for each frame at a sample rate of 24 frames per second. Scaling information was determined by using the diameter of the main gear. The main gear height above the ground for each frame was calculated by multiplying the digitized height and the scaling factor. These heights were then regressed with respect to time. Sink rate equals the slope of this regression line. The main gear sink rate was determined to be 2.20 feet per second. The graph of the main gear height versus time is shown on Figure 2.6.1.1a.

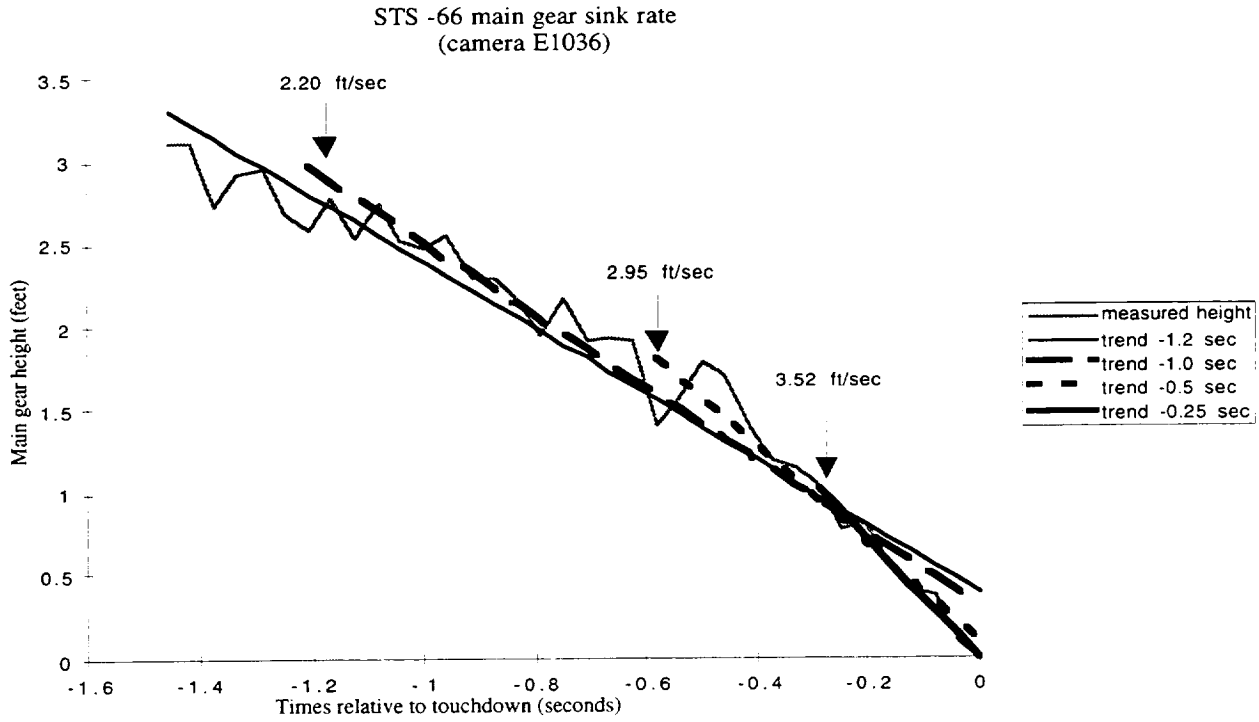


Figure 2.6.1.1a Graph of Right Main Gear Height Versus Time Prior to Touchdown from Film.

Camera E-1008 was used to determine the landing sink rate of the nose gear. The analysis considered approximately one second of imagery immediately prior to touchdown. Data was gathered at a sample rate of 25 frames per second. The nose gear sink rate was determined to be 5.59 feet per second. The graph of the nose gear height versus time is shown on Figure 2.6.1.1b.

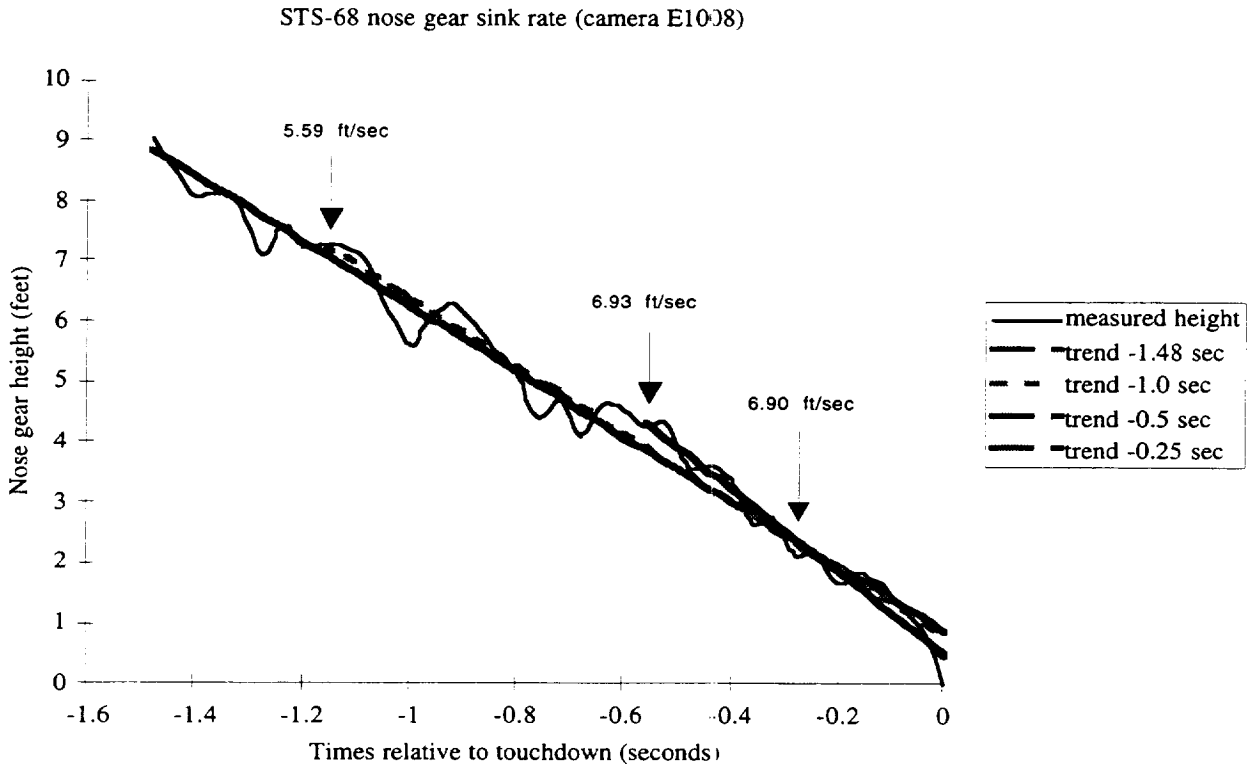


Figure 2.6.1.1b Graph of Nose Gear Height Versus Time during Rollout from Film.

2.6.1.2 Landing Sink Rate Analysis Using Video
(Cameras TV-3, NASA SELECT)

Camera TV-3 was used to determine the landing sink rate of the main gear. The analysis considered approximately one second of imagery immediately prior to touchdown. Data was gathered at a sample rate of 30 frames per second. The main gear sink rate was determined to be 2.51 feet per second. The graph of the main gear height versus time is shown on Figure 2.6.1.2a.

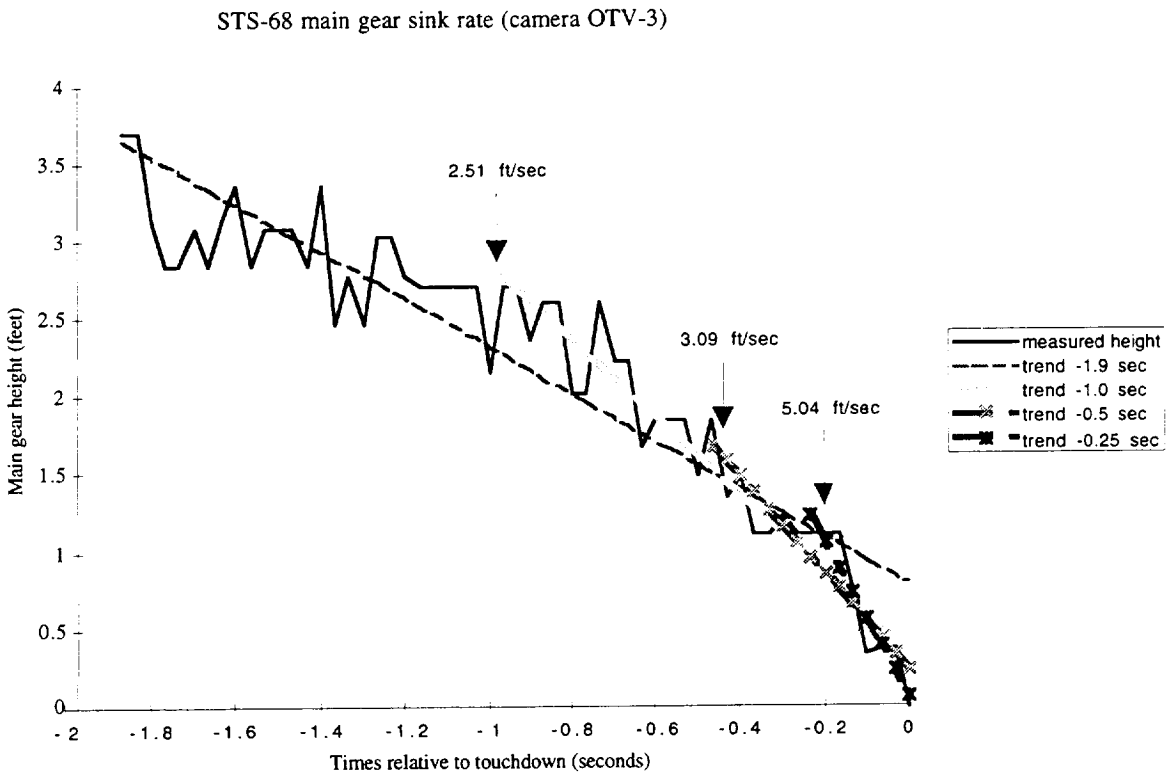


Figure 2.6.1.2a Graph of Right Main Gear Height Versus Time Prior to Touchdown from Video.

Camera NASA SELECT was used to determine the landing sink rate of the nose gear. The analysis considered approximately one second of imagery immediately prior to touchdown. Data was gathered at a sample rate of 30 frames per second. The nose gear sink rate was determined to be 6.19 feet per second. The graph of the nose gear height versus time is shown on Figure 2.6.1.2b.

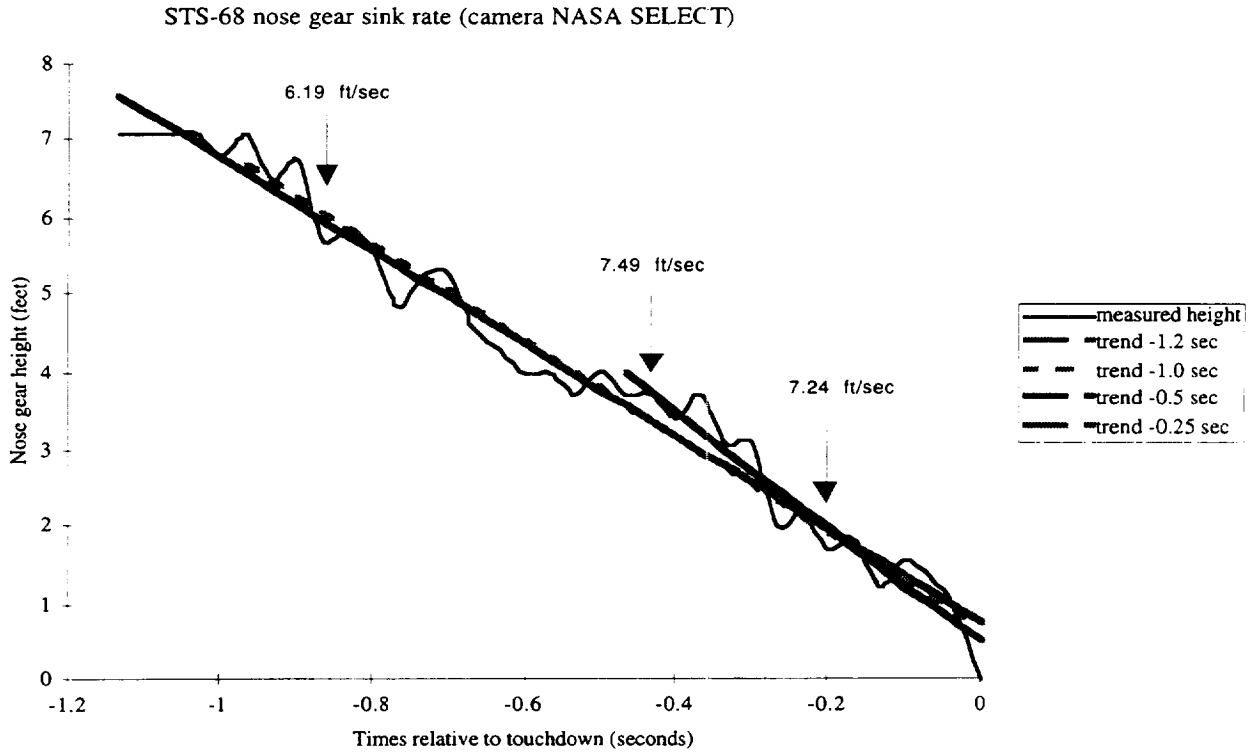


Figure 2.6.1.2b Graph of Nose Gear Height Versus Time during Rollout from Video.

2.6.2 Drag Chute Performance (Task #9)

The landing of Endeavour at the end of mission STS-68 marked the eighteenth deployment of the Orbiter drag chute. The deployment of the drag chute appeared as expected. Event times were obtained from camera DTV-1. See section 1.1.3.

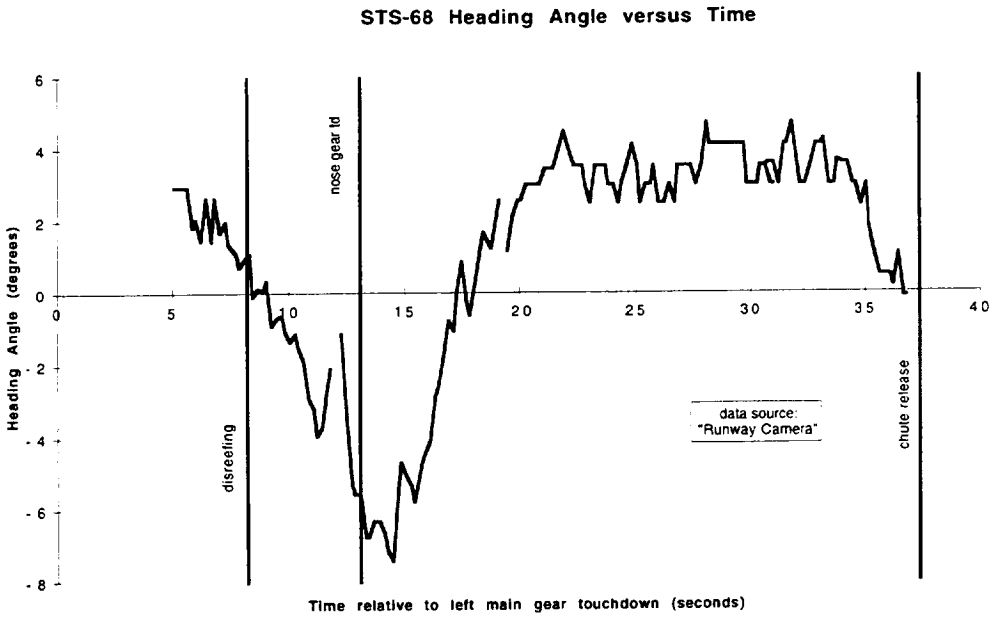


Figure 2.6.2.1 Heading Angle Versus Time.

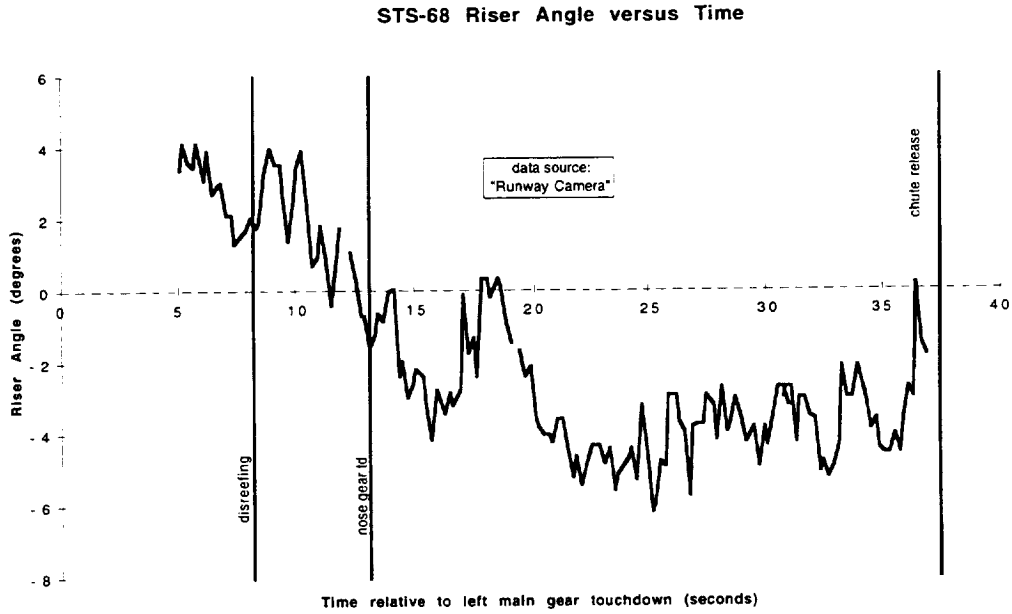


Figure 2.6.2.2 Riser Angle Versus Time.

Standard analysis of the drag chute angles as a function of time was performed using the views from the video camera labeled "Runway Camera" then verified with the film cameras E-1030 and E-1031. This analysis is used to support the improvement of the aerodynamic math models currently in use. Figure 2.6.2.1 presents the measured heading angle versus time. Figure 2.6.2.2 presents the measured riser angle versus time. The maximum measured horizontal chute deflection (heading angle) was approximately

7.4 degrees to the port side of the vehicle. The vertical chute deflection (riser angle) ranged from -6.2 to +4.2 degrees relative to the Orbiter coordinate system.

2.6.3 Orbiter Height above Threshold (Task #13)

The height of the Orbiter above the threshold at landing for the STS-68 mission was not completed at the time of this report. The analysis request specifies that a camera with a perpendicular view of the runway at the threshold location be used for the analysis. This view is currently only available for landings at KSC. This analysis task will be completed using alternative developmental methods as time is available.

2.7 OTHER NORMAL EVENTS

Other normal events observed include: normal SSME ignition sequence, body flap vibration after SSME ignition, ET twang prior to liftoff, frost on the ET vent louvers prior to liftoff, right and left inboard and outboard elevon vibration after SSME ignition and at liftoff, RCS paper debris after SSME ignition, multiple pieces of white debris (probably ice from the ET/Orbiter umbilicals) fell along the body flap after liftoff, ice and vapor from the GUCP area during ET GH2 umbilical vent arm retraction, vapors from the ET gaseous hydrogen umbilical disconnect during early liftoff, multiple pieces of dark debris in the exhaust cloud after liftoff, acoustic waves in the SRB exhaust plume after liftoff, multiple pieces of light colored debris noted aft of the SLV before, during, and after the roll maneuver, vapor from both SRB stiffener rings after liftoff, ET aft dome outgassing, charring of the ET aft dome, flares in the SSME exhaust plume after the roll maneuver, condensation around SLV after the roll maneuver, SRB plume brightening prior to SRB separation, SRB separation, and slag in the SRB exhaust plume after SRB separation.

Normal pad events observed were hydrogen ignitor operation, fixed service structure (FSS) deluge water spray activation, sound suppression water initiation, multiple pieces of light colored debris falling from the FSS during SSME ignition, latch back of the GH2 vent arm, and MLP deluge water operation.

2.8 STS-68 ABORT ANALYSIS (TASK #14)

On August 18, 1994, the launch of Endeavour (OV-105) was aborted at T-1.9 seconds prior to liftoff.

Figure 2.8a SSME #3 Shutdown on STS-68 Abort
(Camera OTV-070).

Eight videos of the launch abort were screened and a report was distributed on August 18, 1994. Eighteen high speed films were screened on August 24, 25, and 26, 1994. Views from cameras OTV-009, OTV-050, OTV-051, OTV-054, OTV-063, OTV-070, OTV-071 and film cameras E-2, E-5, E-19, E-20, E-77, and E-79A were used to compile a event timeline. The STS-68 abort events were compared to the visual timeline for the STS-51 abort.

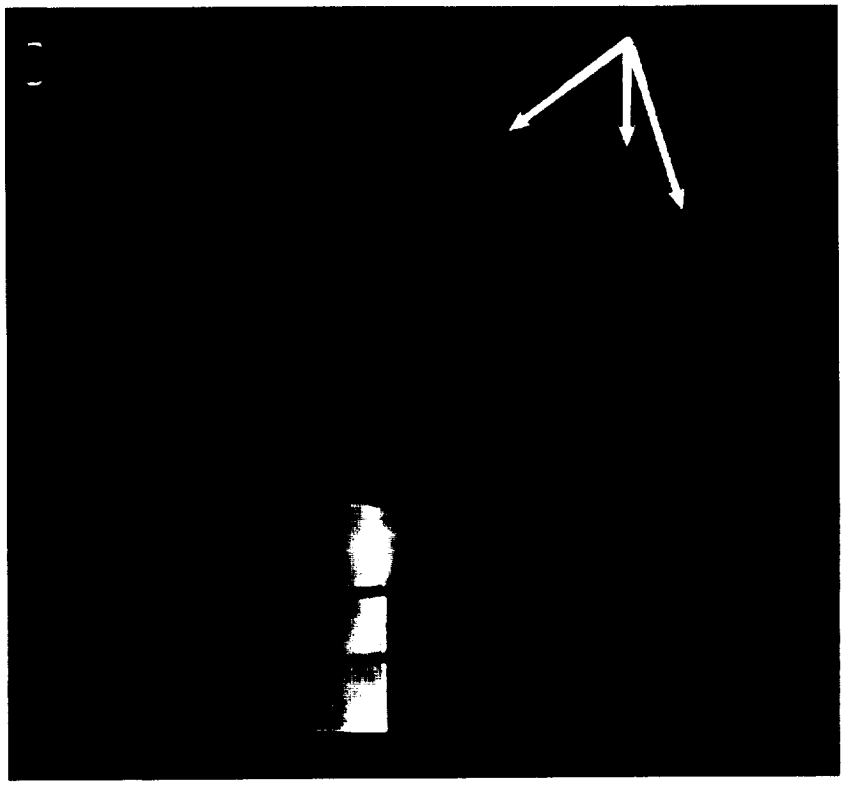


Figure 2.8b Orange Vapor during STS-68 Abort *(Camera OTV-070).*

The amount of orange vapors present on the STS-68 abort appeared less than that of STS-51. The view of these vapor may have been inhibited by early morning lighting conditions during the STS-68 launch. There were little or no indications of flames on STS-68 (in contrast to STS-51). The bright pulses noted on some of the STS-68 camera views were compared to STS-56 (a night launch). On both missions, the SSME yellow burst events appeared as three bright pulses. The fourth and fifth bright pulses are not as predominant as the first three and appear to be normal brightenings that occur prior to Mach diamond formation. The abort screening analysis and the events timeline were provided to the JSC Mission Evaluation Room (MER) manager.

2.9 OTHER

2.9.1 Film Screening for Missing Tile near Orbiter Overhead Window (W8)

(Tracking cameras E-54, E-59, E-204, E-207, E-213, E-220, E-222, E-223, and all launch videos)

Launch views of the Orbiter overhead window were screened for indications of the presence or absence of the tile missing along the inboard aft edge of the port side overhead window (W8). The presence or absence of this tile during ascent could not be confirmed from the launch camera views. The level of detail visible was not adequate to resolve individual tiles in the vicinity of window W8. The general area of the missing tile appeared white in color with no discolorations or

other indications of damage on the best available views. Sun glare and/or view angle hindered the analysis.

The Orbiter post-landing examination revealed that the missing tile may have impacted both payload bay doors and struck the right OMS pod. In a brief conversation with John Kowal/ES3 (TPS Subsystem Manger), a direct line of Orbiter impact points lead to the tile damage location on the right OMS pod from the missing port side tile.

2.9.2 Terminal Events Timing Interval (Task #11)

A detailed timeline of the SSME and SRB ignition sequences was generated and sent to R. Fletcher/JSC-VF5.

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

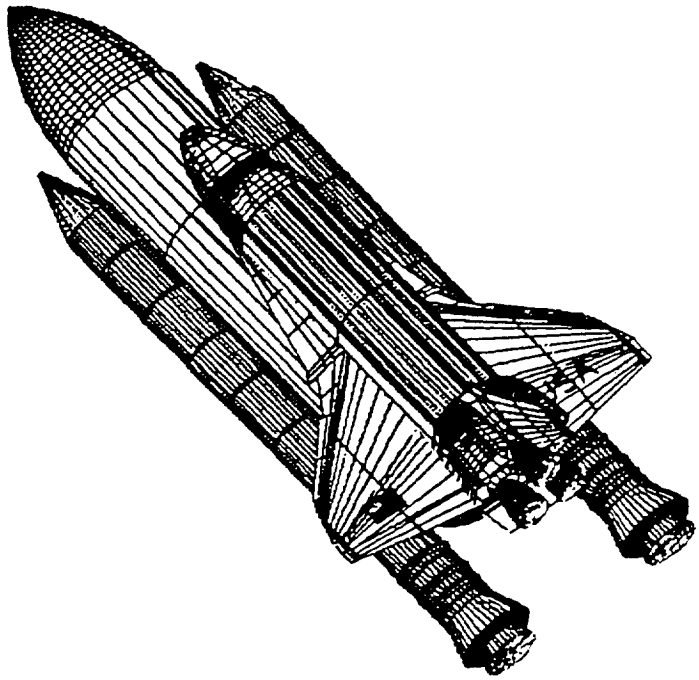
National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-68



MSFC - Form 454 (Rev. October 1992)

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

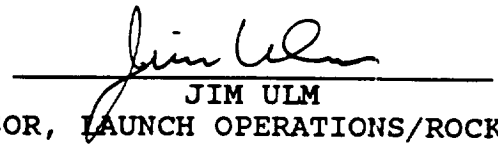
STS-68

FINAL

PREPARED BY:

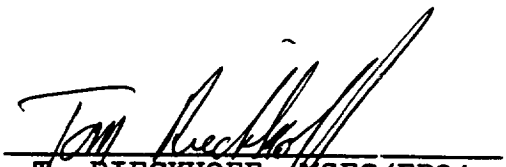
M. COVAN, J. HIXSON
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

SUBMITTED BY:



JIM ULM
SUPERVISOR, LAUNCH OPERATIONS/ROCKWELL/HSV

APPROVED BY:



T. RIECKHOFF, MSFC/EP24
B. LINDLEY-ANDERSON, MSFC/EP24

STS-68 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

TABLE OF CONTENTS

* Photographs in the individual camera assessments are representative photographs and are not necessarily photographs taken from this particular launch.

October 21, 1994

I. INTRODUCTION

The launch of space shuttle mission STS-68, the seventh flight of the Orbiter Endeavour occurred on September 30, 1994, at approximately 6:16 A.M. Central Daylight Time from Launch Complex 39A (LC-39A), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage exists and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard the vehicle, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-68 included, but were not limited to the following:

a. Overall facility and shuttle vehicle coverage for anomaly detection
b. Verification of cameras, lighting and timing systems
c. Determination of SRB PIC firing time and SRB separation time
d. Verification of Thermal Protection System (TPS) integrity
e. Correct operation of the following:
    1. Holddown post blast covers
    2. SSME ignition
    3. LH2 and LO2 17" disconnects
    4. GH2 umbilical
    5. TSM carrier plate umbilicals
    6. Free hydrogen ignitors
    7. Vehicle clearances
    8. GH2 vent line retraction and latch back
    9. Vehicle motion

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-two of fifty-three requested cameras as well as video from twenty-two of twenty-two requested cameras. The following table illustrates the camera data received at MSFC for STS-68.

Camera data received at MSFC for STS-68

	16mm	35mm	Video
MLP	22	0	4
FSS	7	0	3
Perimeter	3	2	6
Tracking	0	15	9
Onboard	2	1	1
Totals	34	18	23
Total number of films and videos received:			75

An individual motion picture camera assessment is provided as Appendix B. Appendix C contains detailed assessments of the video products received at MSFC.

a. Ground Camera Coverage:

All ground cameras operated properly except for camera E-62 which provided no data. Most film exposures were dark resulting in low contrast photographs. The dark exposures were due to the insufficient light levels experienced during sunrise.

b. Onboard Camera Coverage:

Downlink video from the handheld camcorder was received. This video shows approximately 6:45 of good quality video of the ET after separation. Thirty-eight frames of the ET were recorded by the astronauts while performing DTO-0312. These photographs show all sides of the ET and were of excellent quality. Thirty-five millimeter and 16mm films were received from the orbiter umbilical well cameras. All cameras operated properly.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These events consist of ice/frost falling from the 17 inch disconnects during SSME ignition and launch, small pieces of debris such as butcher paper and paper hydrogen fire detectors falling aft during ascent, debris induced streaks/flares in the SSME plumes, glowing debris particles exiting the SRM plumes and slag from the SRM's prior to and during SRB separation.

A streak in SSME#1 was observed at liftoff from cameras E-2 and E-19. This event is shown in Figure 1. The streak is not typical of outside debris contamination.

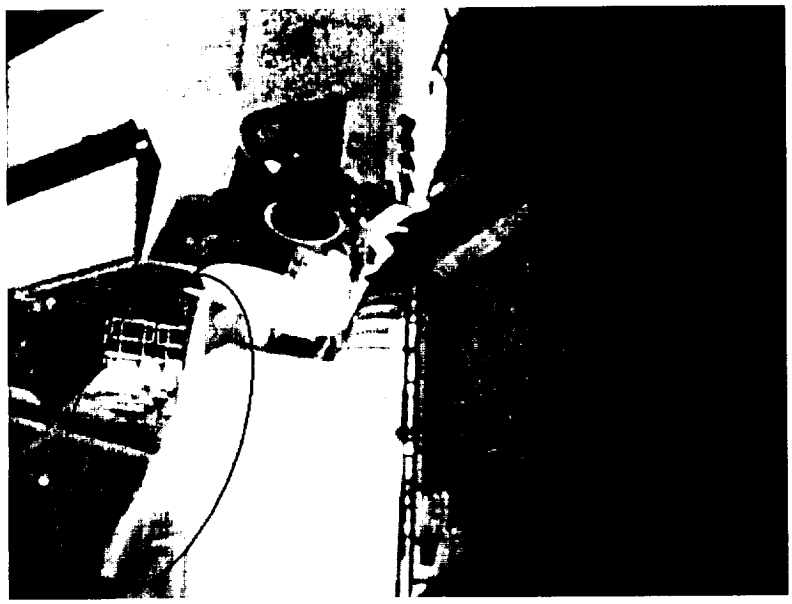


Figure 1 Streak in engine 1

Debris (most likely water baggie material) from the SRM ignition fell onto the right SRB aft skirt at holddown post M-2. This debris is shown in Figure 2. No damage was observed.

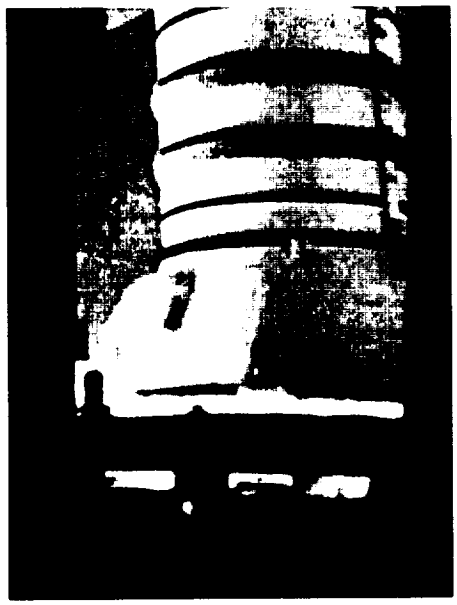


Figure 2 Debris striking RSRB aft skirt

Coverage from the astronaut hand-held camera shows the tank to be in good condition with only two divots located at the intertank/LH2 tank scarf joint. These divots are located in the

-Z area of the tank. Two divots were also observed on the LH2 tank acreage near the -Y axis. A picture from the hand-held camera is provided as figure 3. A divot located along a stringer on the intertank was observed from the umbilical well cameras. This divot is in line with the +Z axis.

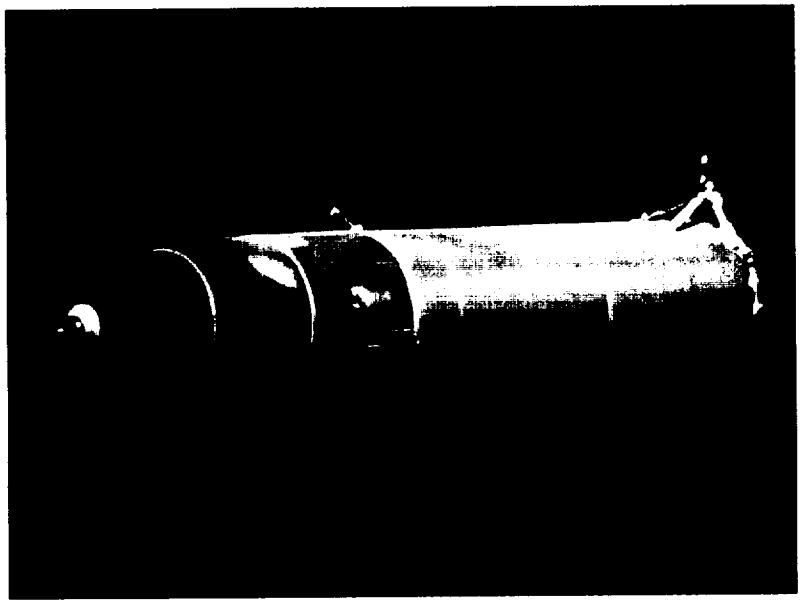


Figure 3 Film frame from hand-held camera

b. Debris/Vapors Near OMS Pod

White vapors were observed passing over the right OMS pod at approximately T+36 seconds from several tracking cameras. Figure 4 is a film frame from camera E-207 showing these vapors.

Figure 4 White vapors passing over right OMS pod

A white debris object was also observed in this region as seen in Figure 5 which is from camera E-222.

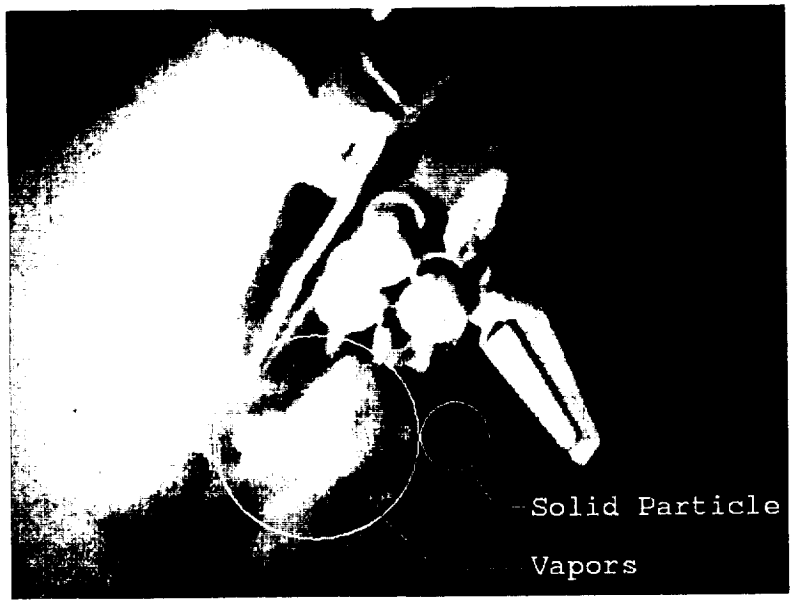


Figure 5 White debris object near right OMS pod

The source of the vapors cannot be determined. Lighting conditions preclude good observations forward of the vehicle. Possible evidence of these vapors passing over the payload bay doors was noted by a change in lighting\shadow conditions in camera TV-4.

At T+43 seconds debris was seen passing by the vertical stabilizer. This event is shown in Figure 6 which is from camera E-207.

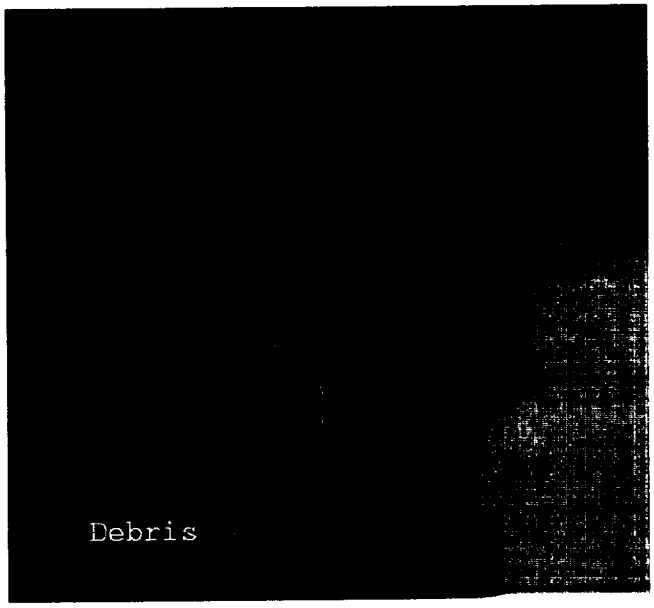


Figure 6 Debris object near vertical stabilizer

Identification of this debris is not possible forward of the vertical stabilizer. However, this debris appears typical of RCS motor cover paper.

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times are determined from cameras that view the SRB holddown posts numbers M-1, M-2, M-5 and M-6. These cameras record the explosive bolt combustion products.

HOLDDOWN POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	273:11:16:00.018
M-2	E-8	273:11:16:00.019
M-5	E-12	273:11:16:00.019
M-6	E-13	273:11:16:00.017

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 31 inches. Figure 7 is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. A positive horizontal displacement represents motion in the -Z direction. These data were derived from film camera E-79A.

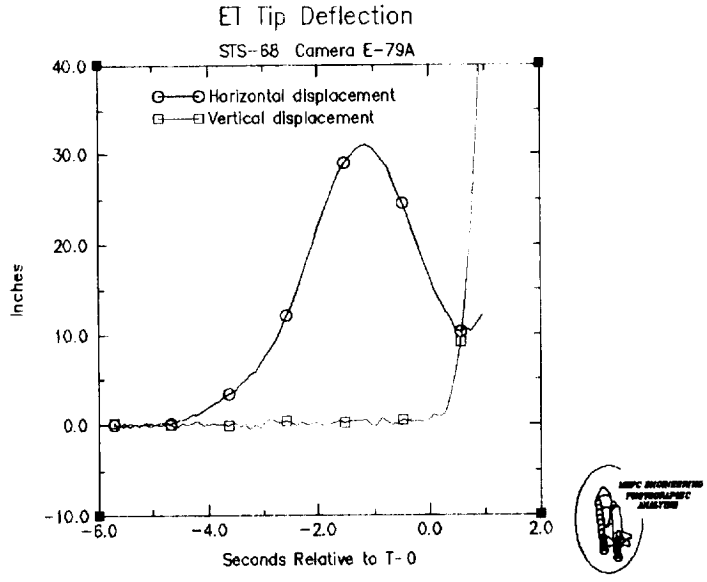


Figure 7 ET Tip Deflection

c. SRB Separation Time:

SRB separation time for STS-68 was determined to be 273:11:18:03.71 UTC as recorded by tracking cameras E-212 and E-208.

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A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-68. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-68, and the resulting effect on the Space Shuttle Program.

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